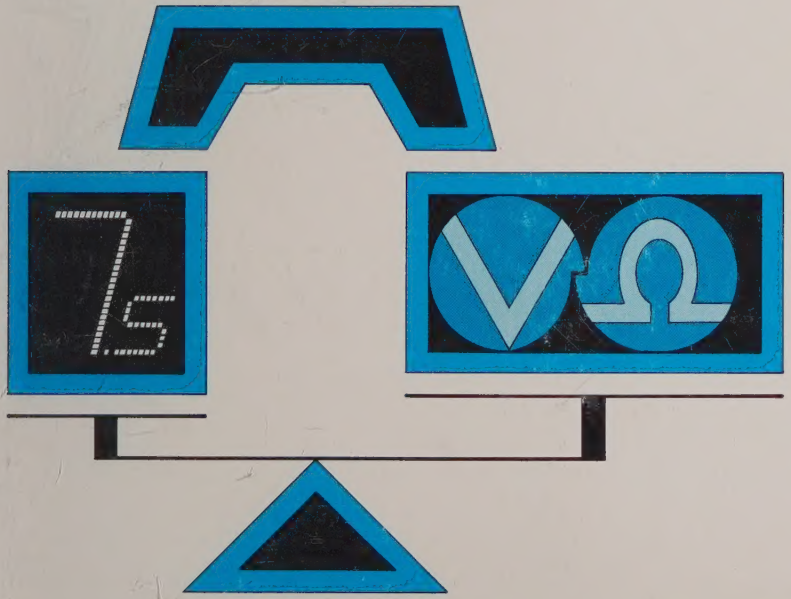
INSTRUCTION MANUAL

3300

DIGITAL MULTIMETER



DANA®

PUBLICATION NO. 980451

INSTRUCTION MANUAL

MODEL 3300

DIGITAL MULTIMETER

INTERTYME METROLOGY
Laboratory, Inc.
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Sunnyvale, Calif. 94086

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IRVINE, CALIFORNIA 92664

DANA®

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TELEX 678-341

WARRANTY

Within one year of purchase, Dana Laboratories will repair or replace your instrument, at our option, if in any way it is defective in material or workmanship. All parts and labor charges will be paid by Dana Laboratories. Just call Dana Product Service at (714)833-1234 collect in California, for assistance. We will advise the proper shipping address for your prepaid shipment. Your instrument will be returned to you freight prepaid.

NOTE

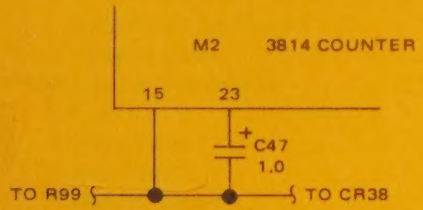
Dana buys the best batteries obtainable from battery manufacturers and each unit is tested before installation in the DMM. However, due to inherent variance between individual cells and unpredictability of charge-discharge patterns, batteries are specifically excluded from the Dana parts warranty.

CONTROLLED DOCUMENT
3300
DIGITAL METER
CONTROL # E-3303
DATE: 09/22/94
IML 21 QA

ERRATA SHEET

Page 6-3, Figure 6.1

Capacitor C47 added between M2-15 and M2-23:



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OVERLOAD
LINE POWER
RANGE
FUNCTION
DANA
DIGITAL MULTIMETER MODEL 3300

SECTION 1 GENERAL DESCRIPTION

1.1 INTRODUCTION.

1.2 The Dana Model 3300 Digital Multimeter (DMM) is a three-digit instrument with capability of measuring d-c voltage and resistance on five ranges and a-c voltage on four ranges. A fourth digit provides 100% overrange on all functions. When equipped with the optional battery pack, the instrument is completely portable.

1.3 Light-emitting diodes (LED's) are utilized in the numerical display. An automatic intensity circuit adjusts the brightness of the display for prevailing light conditions and a blanking circuit removes all insignificant zeros on the readout. A unique set of cams on the FUNCTION and RANGE switches prevents the selection of "illegal" range-function combinations. Autopolarity circuits select and display polarity automatically.

1.4 OPTIONS.

1.5 Battery Pack.

1.6 With the battery pack, the instrument operates on power line voltage (115V or 230V) or on self-contained nickel cadmium batteries. The batteries provide eight hours of continuous operation and charge fully in 16 hours of line voltage operation.

1.7 A battery (BATT) position on the FUNCTION switch allows the user to monitor the charge on the battery pack at any time. The reading obtained is easily converted to remaining discharge time (see Battery Operation, 2.17). When the battery discharges to 5.5 volts, the battery pack is automatically disabled to prevent overdrain and possible damage to the batteries. Recharging occurs whenever the instrument is operated on power line voltage.

1.8 Current Shunt Set.

1.9 The current shunt set extends instrument capability to include a-c or d-c current measurement on five ranges: 100 μA, and 1, 10, 100, and 1000 mA. The 100 μA range provides resolution of 10 nA.

1.10 The shunt set consists of five color-coded shunts which are stored on a holder at the lower front of the instrument. For measurement, the shunt for the desired range is plugged into the input terminals of the instrument with the RANGE set to 1V.

1.11 Rack-Mounting Flanges.

1.12 With these special flanges mounted on either side of the instrument case, the 3300 can be mounted in a standard 19-inch rack or cabinet.

1.13 Carrying Case.

1.14 This rugged simulated-leather carrying case provides maximum protection while maintaining portability of the instrument. An opening at the rear of the case for the power cable enables line-voltage operation and/or battery charging.

1.15 MECHANICAL DESCRIPTION.

1.16 Case.

1.17 The instrument case is made of lightweight plastic (LEXAN) that is virtually unbreakable. Because the instrument operates at a low temperature, the case has no ventilation louvers. This permits operation under environmental conditions where dust, dirt, and water present problems to instrument performance.

1.18 Front Panel.

1.19 Mounted on the front panel are the input terminals, the RANGE switch, and FUNCTION switch and the readout "window".

1.20 Rear Panel.

1.21 On the rear panel is the power connector, 115V fuse, a 230V fuse, and a switch for either 115V or 230V power line voltage.

1.22 Main PC Board.

1.23 The main p-c board (or "motherboard") contains the power supply, all analog circuits, and all digital circuits except for the LED readout board.

1.24 Readout Board.

1.25 The readout board plugs into a connector on the main board directly behind the readout window. It contains the LED's and associated readout components.

1.26 Battery Pack (Optional).

1.27 The battery pack is suspended over the main board and mounted by screws at the top of the instrument case.

1.28 Current Shunts (Optional).

1.29 The current shunts are stored in a holder that mounts on the lower front of the instrument (replacing the front supporting feet).

1.30 ELECTRICAL DESCRIPTION.

1.31 The Model 3300 DMM uses the dual slope method of analog to digital conversion. In this method, the input signal is converted into a proportional current and integrated across a capacitor for a predetermined time period (50 ms), thereby establishing a voltage vs. time relationship. The capacitor is discharged at a linear rate by a fixed reference current generator. The time required for the capacitor to discharge is measured and displayed.

1.32 The majority of the digital circuitry is contained in a single counter/multiplexer integrated circuit (IC). This IC performs the counting, latching, multiplexing and blanking functions, as well as providing timing signals for the integration sequence. The analog portions of the instrument consist of integrated operational amplifiers and discrete components and are used for current conversion, signal conditioning (ac and resistance conversion) and integration functions.

1.33 SPECIFICATIONS.

1.34 Specifications are listed in Table 1.1. Test procedures for verification of specifications are given in Section 3.

Table 1.1 - Specifications

DC VOLTAGE	
Ranges:	±.1, ±1, ±10, ±100, ±1000V
Overrange:	100% on all ranges (±1000V maximum input)
Resolution:	.1% of range (100μV on .1V range)
Accuracy:	1, 10, 100, 1000V ranges 90 days, 23°C ±5°C ±(.1% R + .1% F.S.) 6 months, 23°C ±5°C ± (.15% R + .1% F.S.) .1V range 90 days, 23°C ±5°C ± (.1% R + .1% F.S.) 6 months, 23°C ±5°C ± (.15% R + .1% F.S.)
Polarity:	Automatic Bipolar
Temperature Coefficient:	1, 10, 100, 1000V range ±(.01% R + .01% F.S.)/°C .1V range ±(.01% R + .02% F.S.)/°C
Input Resistance:	.1 and 1V ranges 1000 Mohms Other ranges 10 Mohms
Normal Mode Noise Rejection:	At or near line frequency 40 dB
Common Mode Noise Rejection: (1 KΩ imbalance)	Line operated 120 dB @ DC 100 dB @ 50 Hz Battery operated Near Infinite
Overload	±1000V may be applied to any range without damage
Settling Time:	Less than one second to 0.1% F.S.
Digitizing Time:	Less than 150 msec.

GENERAL	
Maximum Power Requirement:	10 watts, 50 to 400 Hz 90 to 125V or 180 to 250V (switch selectable) Operation while charging battery 100 to 125V or 200 to 250V
Dimensions:	8.5 inches wide (216 mm) 3.5 inches high (89 mm) 11 inches long (279 mm)
Weight:	Without batteries — 5.5 pounds (2.5 Kg) With batteries — 7.5 pounds (3.4 Kg)
Battery:	Operating time — 8 hours at 23°C Recharge time — 16 hours at 23°C
Ranging:	Manual in all functions
Warm-up Time:	30 minutes tc full accuracy
Operating Temperature:	0°C to 50°C
Storage Temperature:	With batteries, −20°C to +65°C Without batteries, −20°C to +85°C

AC VOLTAGE	
Ranges:	1, 10, 100, 1000V rms
Overrange:	100% on all ranges (±1000V maximum input)
Resolution:	.1% of range (1mV on 1V range)
Accuracy:	90 days, 23°C ±5°C 50 Hz to 10 KHz ±(.2% R + .1% F.S.) 10 KHz to 20 KHz ±(.5% R + .1% F.S.) 6 months, 23°C ±5°C 50 Hz to 10 KHz ±(.3% R + .2% F.S.) 10 KHz to 20 KHz ±(.7% R + .2% F.S.)
Input Impedance:	1 megohm shunted by 100 pF
Overload:	1000V RMS or 500V DC on all ranges
Settling Time:	Less than three seconds to 0.5% F.S.

continued. . .

Table 1.1 - Specifications (Continued)

CURRENT (Shunt Set)

Ranges:	DC Accuracy	AC Accuracy— 50 Hz to 10kHz
100μa	±(.2% R + .1% F.S.)	±(1.0% R + .1% F.S.)
1ma	±(.2% R + .1% F.S.)	±(.3% R + .1% F.S.)
10ma	±(.2% R + .1% F.S.)	±(.3% R + .1% F.S.)
100ma	±(.2% R + .1% F.S.)	±(.3% R + .1% F.S.)
1000ma	±(.4% R + .1% F.S.)	±(.5% R + .1% F.S.)
	Conditions: 90 days, ±5°C	
Overrange:	100% on all ranges	
Resolution:	100 na on 100μa range	
Response Time:	DC <1 second AC <3 seconds	
Overload:	300% of range — 100μa through 100 ma 225% of range — 1000 ma	

RESISTANCE

Ranges:	1K, 10K, 100K, 1M, 10M
Overrange:	100% on all ranges
Resolution:	.1% of range (1 ohm on 1K range maximum)
Accuracy:	90 days, 23°C ±5°C 1, 10, 100 kilohm ranges ±(.2% R + .1% F.S.) 1 & 10 megohm ranges ±(.5% R + .1% F.S.) 6 months, 23°C ±5°C 1, 10, 100 kilohm ranges ±(.3% R + .1% F.S.) 1 & 10 megohm ranges ±(.7% R + .1% F.S.)
Current Through Unknown:	.1 ma maximum
Response Time:	1K-100K 1 second to rated accuracy 1M 4 seconds 10M 10 seconds
Overload:	250V DC or RMS AC on all ranges without damage

(All specifications are subject to change at manufacturer's discretion.)

SECTION 2 INSTALLATION & OPERATION

2.1 UNPACKING AND INSPECTION.

2.2 The Model 3300 Multimeter is secured in two molded, plastic-foam forms firmly packed in a cardboard carton for shipment. The plastic forms hold the instrument securely in the carton and absorb any reasonable external shock normally encountered in transit. Prior to unpacking, examine the exterior of the shipping carton for any signs of damage. Carefully remove the instrument from the carton and inspect its exterior for any signs of damage. If damage is found, notify the carrier immediately.

2.3 Included with the instrument in the packing container are the instruction manual and power cord.

2.4 BENCH OPERATION.

2.5 Each Model 3300 is equipped with a tilt bail or "kickstand" to enable the front of the instrument to be elevated for convenient bench use. The tilt bail is attached to the two front supporting "feet" at the bottom of the instrument. For use, the bail is pulled down to its supporting position.

2.6 INSTALLATION OF ACCESSORIES.

2.7 Rack-Mounting Flanges.

2.8 The instrument can be mounted in a standard 19-inch rack with the optional Rack-Mounting Flanges (403655, includes attaching hardware). To install the flanges, proceed as follows:

a. Remove top and bottom covers of DMM as described under 5.1(a) and 5.2(a) on page 5.1.

b. Remove handle retaining clips by sliding them toward the rear of the case. This frees the carrying strap. Remove strap.

c. Remove front supporting feet and tilt bail from bottom cover by sliding the feet forward. Remove rear feet from bottom cover by pulling up on the outer edge of each foot and sliding it toward the side of the cover (figures 2.1 and 2.2).

d. Drill two .086" diameter holes at the front two drill guides on each side of the case. Attach the pair of mounting flanges with four 4-20 x 1/2" self-tapping screws.

Figure 2.1 - Removal of Front Feet

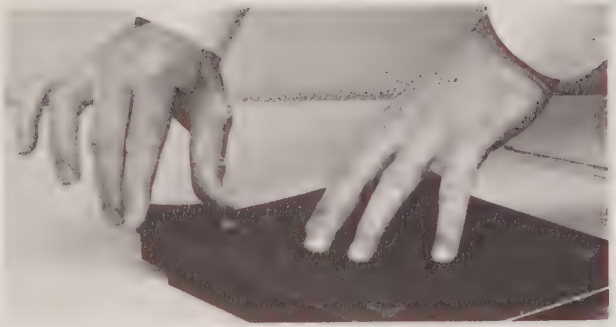


Figure 2.2 - Removal of Rear Feet

e. Replace top and bottom covers. Reinstall mounting screw through bottom cover. Reinstall rear panel retaining screws and tighten. The instrument is now ready for rack-mounting.

2.9 Battery Pack Installation.

2.10 The optional battery pack is factory-installed when ordered with the instrument. For field installation, perform the following procedure.

a. Remove top cover of DMM as described under disassembly step 5.1(a) on page 5.1.

b. Remove mounting screw at the center of bottom cover of instrument.

c. Remove bypass connector P2 from J2; install P2 onto keeper on battery pack PC board (figure 2.3) for storage.

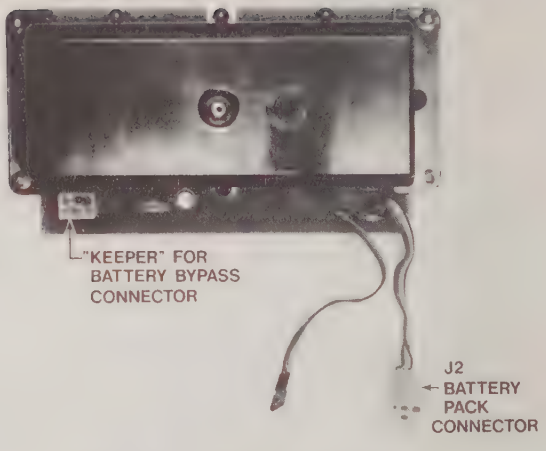


Figure 2.3 - Battery Pack Connector

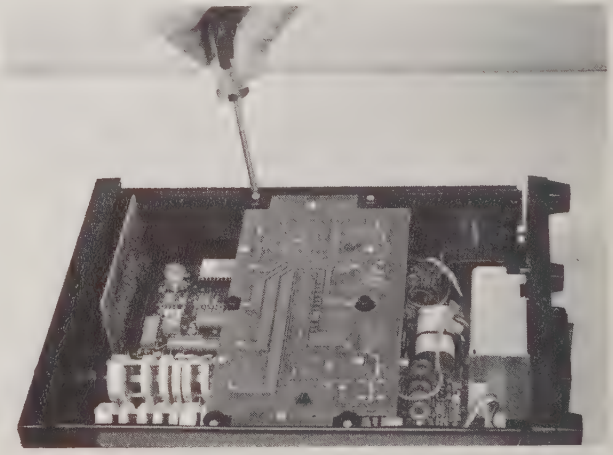


Figure 2.4 - Battery Pack Mounting Screws

NOTE

Bypass connector P2 must be connected to J2 when the instrument is operated on line voltage with the battery pack removed.

d. Place the battery pack into position at the top of the instrument and install the four mounting screws through the top of the battery pack (figure 2.4).

e. Reinsert bottom mounting screw and tighten firmly.

f. Connect P2 (on battery pack cable) to J2. Attach battery pack power transistor to unused transistor retaining clip (on rear panel shield).

g. Replace top cover. Tighten rear panel retaining screws. The instrument is now ready for battery operation.

2.11 Current Shunt Installation.

2.12 When the current shunt option is ordered with the instrument, it is delivered with the current shunt holder installed. The holder replaces the front supporting "feet" of the instrument and contains receptacles for convenient storage of the shunts. For field installation of the current shunt holder, proceed as follows:

a. Remove top and bottom covers of DMM as described under disassembly step 5.1(a) on page 5.1.

b. Remove the front supporting feet and tilt bail from bottom cover by sliding the feet forward (figure 2.1).

c. Place the current shunt holder into position at the front of the bottom cover. Slide the slotted feet of the holder onto the cutouts on bottom cover (from which original feet were removed).

d. Place bottom cover onto instrument. Slide cover forward so that it fits firmly into front panel. This secures the current shunt holder onto the bottom of the instrument. Tighten rear panel retaining screws.

e. Reinstall screw in bottom cover. Reinstall tilt bail by inserting one end of bail into hole on inner edge of either of the holder feet. Snap opposite end into hole in other foot.

2.13 AC POWER REQUIREMENTS.

2.14 The Model 3300 operates on line voltages of either 115V (90 to 125V) or 230V (180 to 250V), 50 to 400 Hz. Maximum power requirement is 10 watts. For operation while battery is charging, the voltage should be in the range of 100 to 125V or 200 to 250V.

2.15 A standard power cable having a three-pin plug is supplied with the instrument. It connects to the power connector (figure 2.5) on the rear panel of the instrument. The power line voltage selector switch and two fuses are located behind the access door on the rear panel. The access door can be opened only with the power cable removed from the connector.

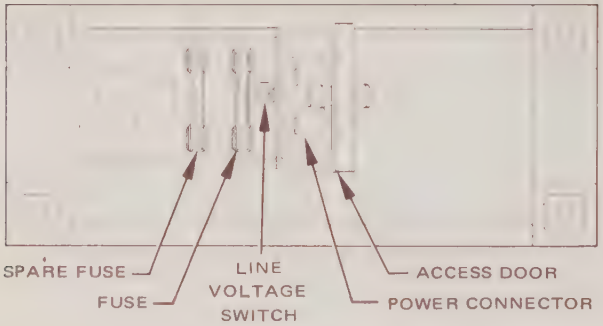


Figure 2.5 - Rear Panel

2.16 The line voltage selector switch is positioned so that the number that is visible on the switch (115 or 230) matches the value of the available line voltage. A 1/4 amp fuse for 230V line voltage and a 1/2 amp fuse for 115V line voltage are provided with the instrument. The proper fuse for the available voltage is installed in the fuse holder nearest the switch. The other fuse holder is for storing the unused (or spare) fuse.

2.17 BATTERY OPERATION.

2.18 The manufacturer's rating of battery life is approximately 200 charge-discharge cycles. However, this can vary greatly depending on the number of complete discharges and the number of partial discharges involved. Generally, a cell which has been consistantly discharged to only one-half of its capacity will supply less energy on subsequent discharges than another cell that has been fully discharged. Allowing the batteries to discharge fully will usually result in more predictable performance.

NOTE

Dana buys the best batteries obtainable from battery manufacturers and each unit is tested before installation in the DMM. However, due to inherent variance between individual cells and unpredictability of charge-discharge patterns, batteries are specifically excluded from the Dana parts warranty.

2.19 Battery voltage can be checked at any time by setting the FUNCTION switch to BATT position. The decimal point is of no significance in this mode. For example, a reading of 62 indicates 6.2 volts. The battery automatically disconnects at 5.5V. It can be restarted, if plugged into line voltage, by turning the FUNCTION switch to OFF (to trigger start-up circuit), then back to a function position. Discharged batteries will restart the instrument long enough for a battery test reading.

2.20 The approximate discharge time remaining can be estimated by use of the graph shown in figure 2.6. The graph was prepared from results of tests of a number of units. The shaded area around the curve indicates the range of test results while the curve itself represents minimum time remaining. Therefore, a reading of 5.9 volts indicates a range of 1/4 to 1-1/2 hours discharge time remaining, depending on the particular set of batteries.

2.21 Battery charge occurs whenever the instrument is operated on power line voltage. With the instrument turned off, but still connected to the line, charging occurs at a higher rate.

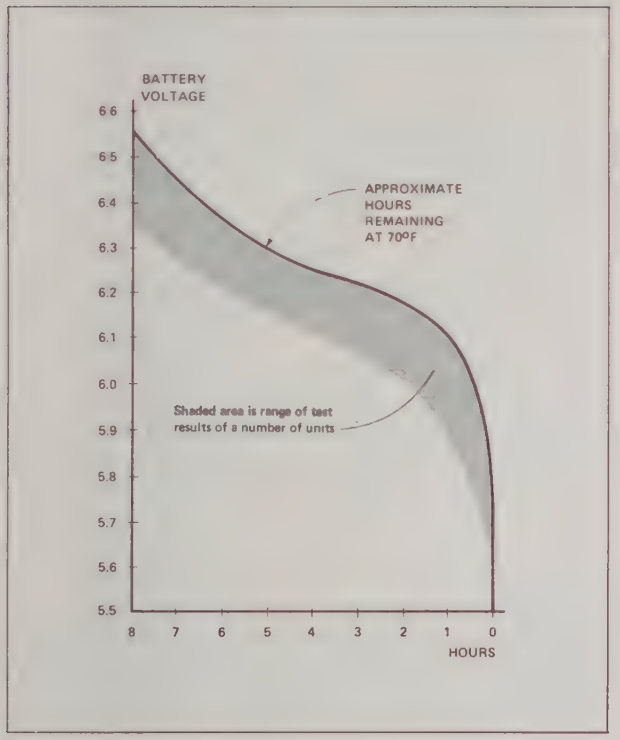


Figure 2.6

2.22 CONTROLS AND INDICATORS (Figure 2.7).

2.23 Function Switch.

2.24 The FUNCTION switch is a five-position rotary switch that is cam-interlocked with the RANGE switch. This feature prevents the selection of an improper function/range combination. The FUNCTION switch selects power off, battery check or any of the three measurement functions (see Table 2.1).

Table 2.1 - Function Switch

OFF	This position removes power to the measurement portion of the instrument. With instruments equipped with the battery pack, the battery charging circuitry continues to operate when the instrument is connected to the power line and the LINE POWER indicator remains lit.
BATT	This position permits the monitoring of the battery pack with instruments equipped with the battery pack. (see 2.19)
ACV	This position selects the measurement of AC volts on the 1, 10, 100, and 1000 volt ranges.
DCV	This position selects the measurement of ± DC volts on the .1, 1, 10, 100, and 1000 volt ranges.
KΩ	This position selects the measurement of resistance with full-scale ranges of 1, 10, and 100 Kilohms and 1 and 10 megohms.

2.25 Range Switch.

2.26 Range is selected by means of the six-position rotary RANGE switch. Function/range combinations and decimal positions are shown in Table 2.2.

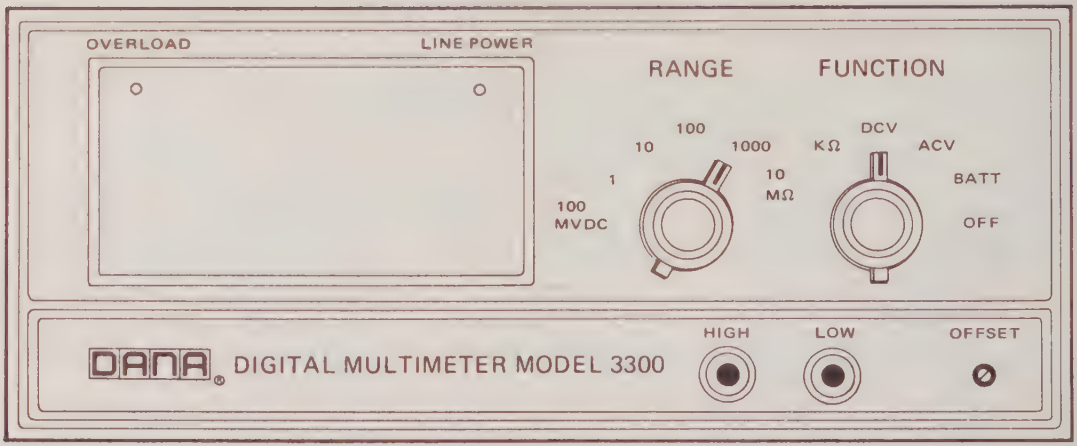


Figure 2.7 - Controls and Indicators

Table 2.2 - Available Ranges

Function			Range	Decimal Position
Ω	AC	DC		
		X	100 mV	000.0
X	X	X	1	0.000
X	X	X	10	00.00
X	X	X	100	000.0
X	X	X	1000	0000.
X			10 MΩ	00.00

2.27 Offset Control.

2.28 The OFFSET control is a screwdriver adjustment that permits the user to zero the instrument. With the instrument on the 100 mV range and the input terminals shorted, OFFSET is adjusted for a display of zero (0.0) on the readout.

2.29 Display.

2.30 The numerical readout consists of four seven-segment LED alpha-numeric devices and one numeral 1/polarity symbol device. The intensity of the readout is automatically controlled and provides maximum brightness in high ambient light and less brightness in low ambient light.

2.31 Non-significant zeros are blanked to simplify readings. In an overload condition, all digits are blanked and the OVERLOAD indicator lights.

2.32 The LINE POWER indicator lights whenever the instrument is plugged into the line, even with the instrument turned off.

2.33 OPERATING PROCEDURES.

2.34 Test Leads.

2.35 The input terminals are a pair of binding posts spaced to accept a standard "banana plug". The binding posts accept single wires also. To connect single wires, loosen the knurled knob of binding post, insert wire through hole in post, and tighten knurled knob.

2.3o It is recommended that 22-gage single-conductor shielded cable be used as test leads. Connect the inner conductor to the HIGH terminal and the shield to the LOW terminal. Convenient terminals for the test end of the leads are alligator clips or mini-clips.

2.37 Measurement Connections (DC and Ohms).

2.38 For all voltage measurements, connect the LOW input to the measurement point nearest ground potential.

2.39 Current Measurements (Optional).

2.40 All current measurements (ac or dc) are made with the instrument on the 1-volt range. The specific range is selected by the current shunt used. The shunts are color-coded and connect directly across the input terminals. The shunts and corresponding ranges are described in Table 2.3.

Table 2.3 - Current Shunt Identification

Color Code	Range	DC Resistance
Black	1 amp	1Ω
Red	100 mA	10Ω
Brown	10 mA	100Ω
Orange	1 mA	1 KΩ
Yellow	100 μA	10 KΩ

SECTION 3 SPECIFICATION TESTS

3.1 GENERAL.

3.2 This procedure is designed to ensure that the instrument is operating properly and within its specifications. If any of the readings are not within tolerance refer to the calibration procedure. If the instrument fails to operate properly, refer to the troubleshooting procedure.

3.3 PREPARATION.

3.4 The DMM requires thirty minutes warmup time. Pre-zero the instrument prior to each accuracy check by selecting DCV, 100 mV range, connecting a jumper across the HIGH and LOW input terminals and adjusting the front panel OFFSET control for a display reading of 000.

3.5 EQUIPMENT.

3.6 A list of required equipment is given in Table 3.1.

3.7 PROCEDURE.

3.8 Connect the DMM and the test equipment as shown in the figure supplied with each accuracy check. Select the controls and input as called out in the tables and monitor the DMM readout for the indicated values.

Table	Title
3.1	Required Equipment
3.2	DC Test
3.3	AC Test
3.4	KΩ/MΩ Test
3.5	Common Mode Noise Rejection Test
3.6	Normal Mode Noise Rejection Test

Table 3.1 - Required Equipment

TYPE	REQUIRED SPECS	SUGGESTED EQUIPMENT
DC Voltage Standard	Adjustable: 0 – 1000V Resolution: 1 μV on 10V range Accuracy: ± .003%	Cohu Model 351
AC Laboratory power source	Variable: 0 to 500V RMS & 20 Hz to 100 KHz. Resolution better than 100 PPM. Harmonic distortion of 0.1% or less. Stability of .01%.	Optimation Type AC 110 (oscillator, matching transformer & power amplifier)
Thermal Transfer voltmeter	AC/DC thermal transfer voltmeter. Ranges: 1 to 500V. Accuracy 0.05% or better.	Holt Model 6 Thermal Transfer Voltmeter
Standard Resistors	1K, 10K, 100K, and 1, 10, and 100 Megohm. All ± .005% except 10 Meg & 100 Meg which are ± .01%.	ESI SR-1 series standard resistors.
1/2W Carbon Resistor	1,000 ohms ± 10%	
1/2W Carbon Resistor	10,000 ohms ± 10%	
Capacitor	1 μF, 100V or more	
Batteries, 2 required	1.5V cells having screw type binding posts.	

Table 3.2 - DC Test

DMM		INPUT SIGNAL		NOMINAL READING	TOLERANCE	
FUNCTION	RANGE	DC VOLTS				
DC	+100 mV	+.100000		+100.0	99.8 to 100.2	
	+1V	+1.000000		+1.000	.998 to 1.002	
	+10V	+10.00000		+10.00	9.98 to 10.02	
	+100V	+100.0000		+100.0	99.8 to 100.2	
	+1000V	+1000.000		+1000.	998 to 1002	
	−1V	−1.000000		−1.000	−.998 to −10.02	

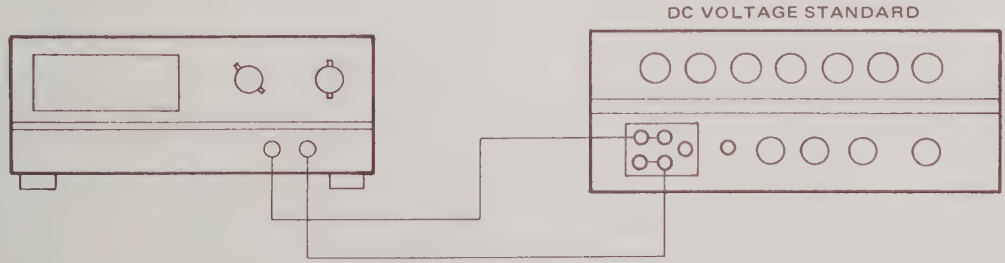


Table 3.3 - AC Test

DMM		INPUT SIGNAL		NOMINAL READING	TOLERANCE	NOTE
FUNCTION	RANGE	AC STANDARD				
AC	1	1.00000	400 Hz	1.000	.995 to 1.005	23°C ± 5°C
	1	1.00000	15 KHz	1.000	.991 to 1.009	
	10	10.0000	400 Hz	10.00	9.95 to 10.05	
	10	10.0000	15 KHz	10.00	9.91 to 10.09	
	100	100.000	400 Hz	100.0	99.5 to 100.5	
	1000	1000.00	400 Hz	1000.	995 to 1005	

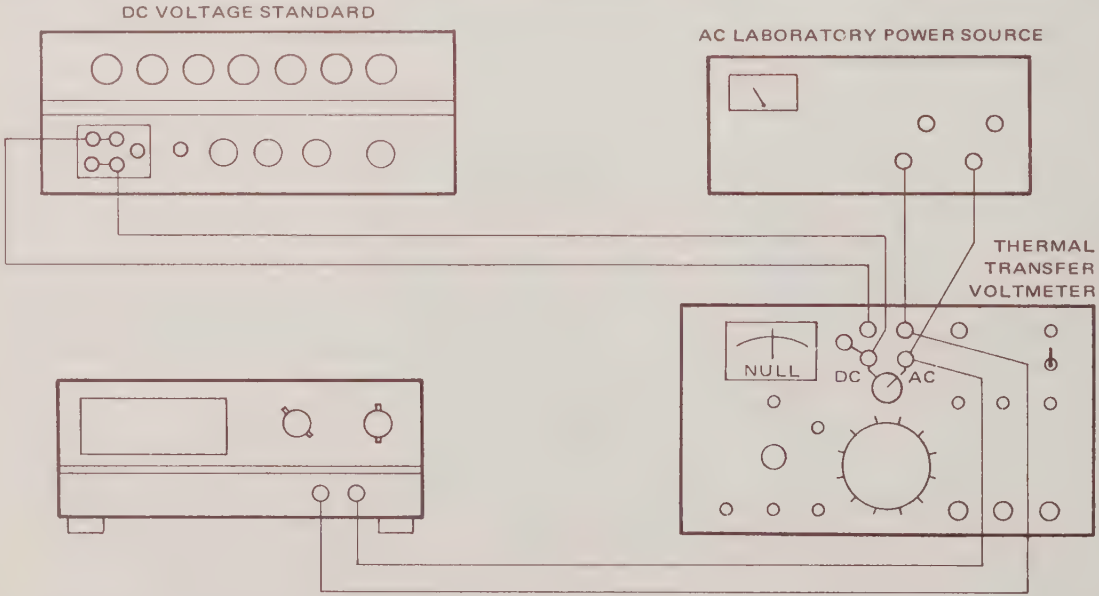


Table 3.4 - KΩ/MΩ Test

DMM		INPUT SIGNAL		NOMINAL READING	TOLERANCE	NOTE
FUNCTION	RANGE	OHMS STANDARD				
KΩ	1	1 KΩ		1.000	.996 to 1.004	23°C ± 5°C
	10	10 KΩ		10.00	9.96 to 10.04	
	100	100 KΩ		100.0	99.6 to 100.4	
	1000	1 MΩ		1000.	992 to 1008	
	10 MΩ	10 MΩ		10.00	9.92 to 10.08	

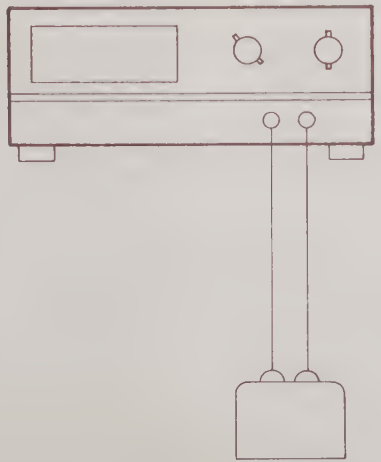


Table 3.5 - Common Mode Noise Rejection Test

DMM		INPUT SIGNAL		NOMINAL READING SEE NOTE 1	TOLERANCE	NOTE
FUNCTION	RANGE	S-1				
DCV	10	GND				1) With switch S-1 in the off position, record the reading displayed in the DMM readout in the NOMINAL READING column. Set S-1 to the AC position for common mode check.
		AC			±1 digit	

NOTE: THE TWO BACK TO BACK 1.5V BATTERIES PROVIDE A SMALL INPUT SIGNAL OF SEVERAL MILLIVOLTS TO OFFSET THE READING FROM ZERO (SINCE NO TWO SUCH BATTERIES ARE EQUAL IN VOLTAGE). THIS AVOIDS POLARITY CHANGES DURING CMR TESTS WHICH MAY MAKE THE READING HARD TO INTERPRET.

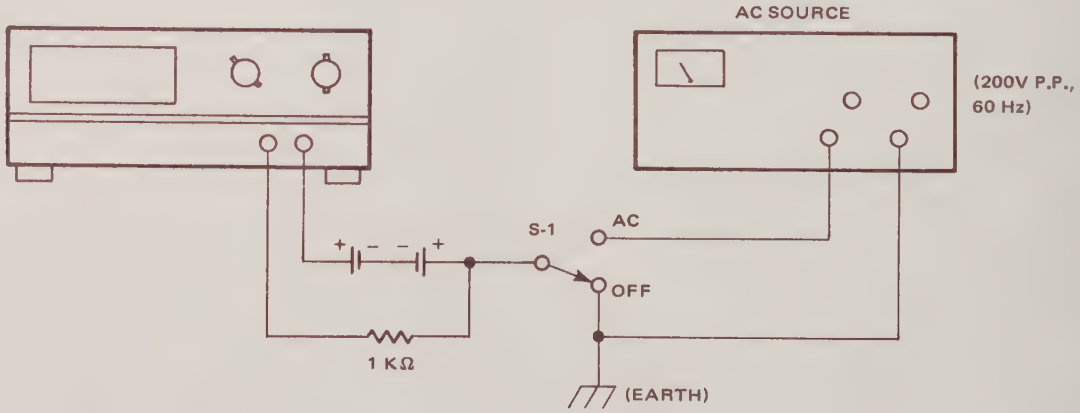
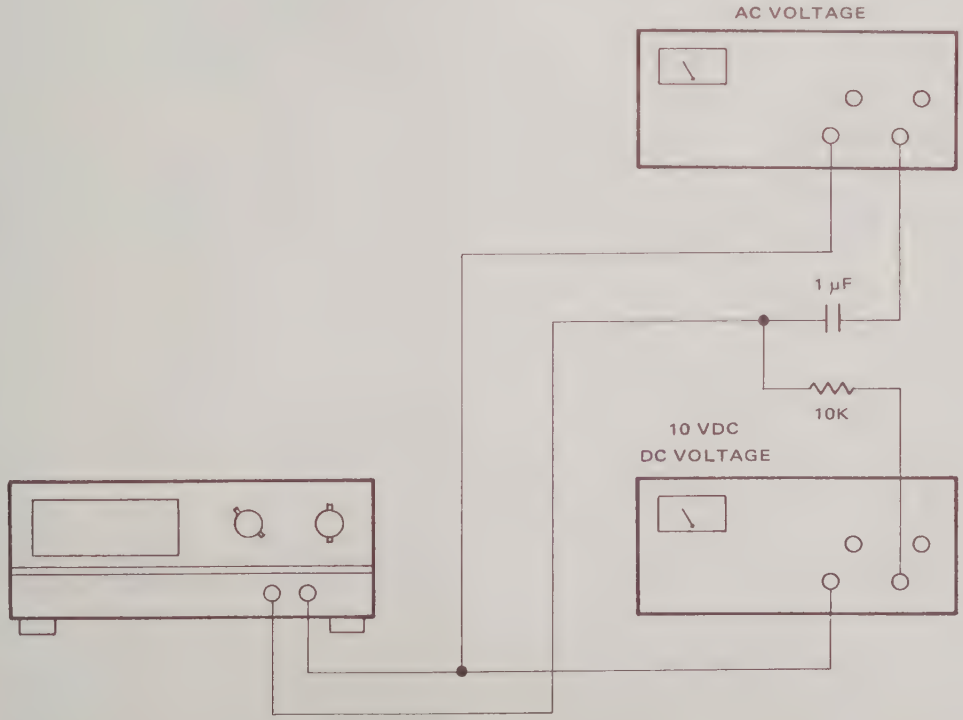


Table 3.6 - Normal Mode Noise Rejection Test

DMM		INPUT SIGNAL		NOMINAL READING	TOLERANCE	
FUNCTION	RANGE	DC	AC			
DC	10	10V	200 mV P.P. 60 Hz	10.00	±1 digit	



SECTION 4 THEORY OF OPERATION

4.1 GENERAL.

4.2 This section describes the operation of the Model 3300 DMM and includes the basic technique used as well as a more detailed explanation of the major functional portions shown in figures 4.2 and 4.11. The drawings contained in this section are included to aid in the description and to supplement the schematics of Section 6.

4.3 The instrument uses the dual slope integration method for analog to digital conversion. As illustrated in figure 4.1, the input signal is converted to a proportional, positive current (I_S) for a set time period (T_0 to T_1). During this time period a voltage is developed across the integration capacitor (C), the value of which is dependent on I_S. A fixed value of negative current (I_R) is then applied to the capacitor. The time required to discharge the voltage across the capacitor (T_1 to T_2) is measured and displayed.

4.4 CIRCUIT DESCRIPTIONS.

4.5 The attenuator, AC converter and Ohms converter perform the signal conditioning function; the G_m converter and digitizer provide the analog to digital conversion. These circuits and the display circuits are shown simplified in figure 4.2. The power supply including the optional battery pack is shown in figure 4.11.

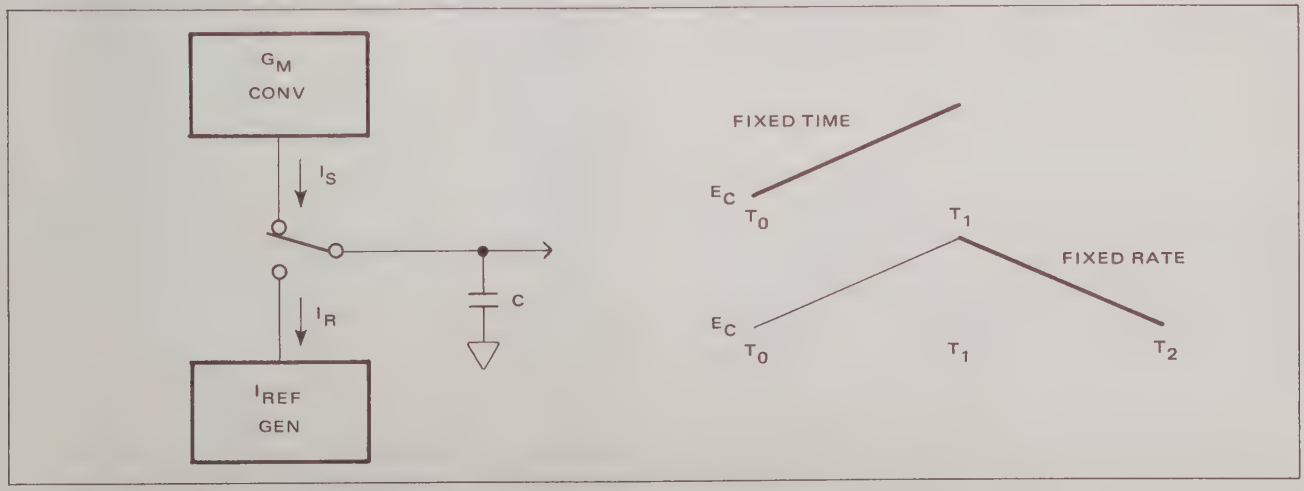


Figure 4.1 - Dual Slope Sequence

4.6 Signal Conditioning.

4.7 ATTENUATOR.

4.8 The attenuator, controlled by the RANGE switch (S1), reduces the level of the input signal to a value acceptable to the measurement circuits. The DCV attenuator consists of series-connected resistors, forming a voltage divider. For measurements on the 10, 100, and 1000 volt ranges, the attenuator reduces full scale inputs to a level of ± 1 volt. No attenuation of the input signal takes place on the 100 millivolt and 1 volt ranges. For ACV measurements, the attenuator is a feedback network for the AC converter. The negative feedback supplied by the attenuator limits the dc output of the AC converter to −1 volt for full scale inputs on all ACV ranges. For kilohms measurements, a tapped resistor string (used as a voltage divider in DCV measurements) is used in conjunction with the ohms reference to produce a fixed current for each ohms range.

4.9 AC CONVERTER.

4.10 The AC converter generates a negative output level proportional to the ac input signal and consists of diodes CR2 and CR3, driven by a high output impedance amplifier (Q4, Q5, and Q6). The ac signal flows through amplifier M5 of the G_m converter which inverts and amplifies the signal, through the converter amplifier and diodes CR2 and CR3. The current flows through each diode alternately dependent on the polarity of the signal and recombines as an ac signal across resistor R32 of the ac attenuator. This ac signal is fed to a summing node at the input of M5 and determines the gain of the network. The negative portion of the ac current flowing through diode CR3 develops a negative half wave voltage across resistors R33 and R34. The half wave signal is filtered and fed to the G_m converter for measurement.

4.11 OHMS CONVERTER.

4.12 The ohms converter consists of a voltage source supplying −1 volt for 10 megohms measurements and −10 volts for measurements on all other ohms ranges. The voltage is fed through a resistive current divider producing a negative current (the value of which is dependent on the range selected) and flows to a summing node at the inverting input of amplifier M5. The output of M5, connected to the LOW input connector, goes positive causing a positive current to flow through the resistor being measured, connected across the input terminals. The current flows through the HIGH input connector to the summing node and the circuit stabilizes when the positive and negative currents are equal. The voltage developed across the unknown resistor is then measured by the remainder of the circuitry.

Q10/Q11 circuitry stabilizes when the current through Q10/Q11 is equal to the current through resistors R35 and R36. The increase in current required for 0.1 volt full scale inputs is derived in the same manner as for positive inputs.

4.17 The offset generator, shown in figure 4.3c, produces a fixed 0.5 μamps of current. Zener diode CR13 provides a stable 3.3 volts across potentiometer R63 and forward biases diode CR9. The current through Q14 is dependent on the voltage across R61. Temperature compensation for the generator is provided by CR9.

4.18 Digitizer.

4.19 REFERENCE SOURCE.

4.20 The reference current source draws a fixed and stable 0.5 milliamps of current (I_R) from the integrating capacitor during the reference integration period. The source, shown simplified in figure 4.4, consists of two

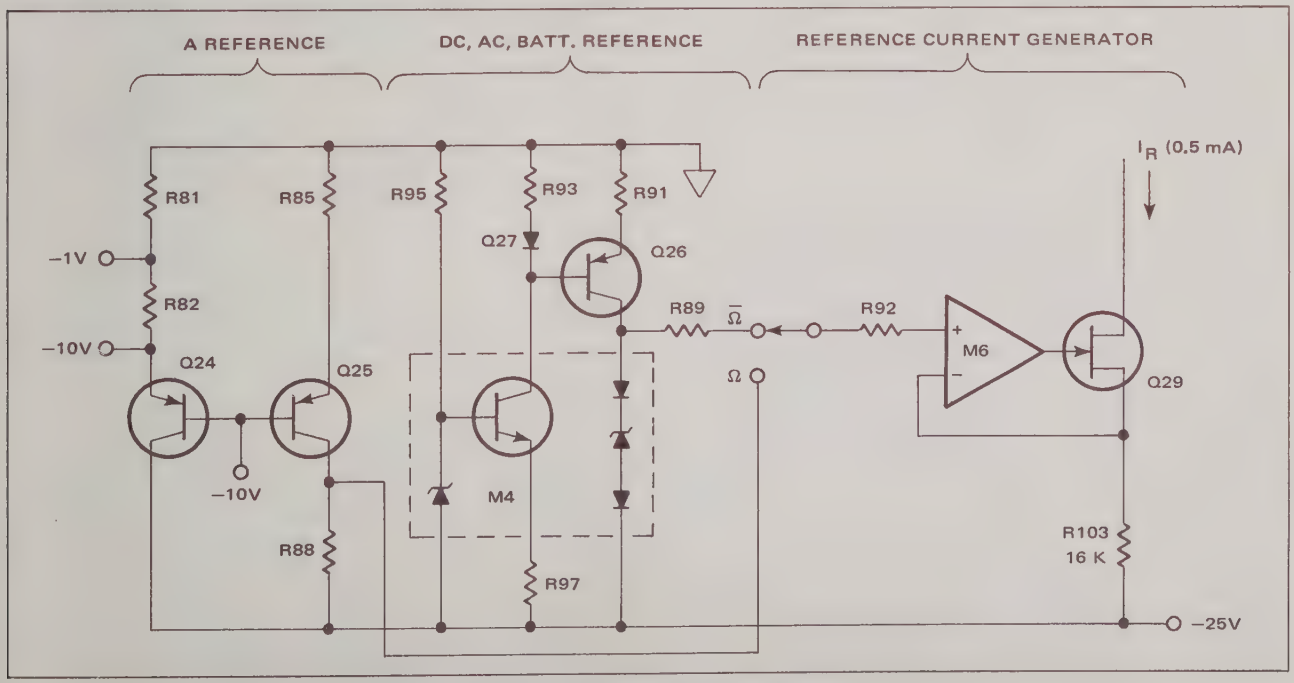


Figure 4.4 - Reference Current Source

voltage sources (one for ohms measurement and the other for voltage measurement) and a current generator.

4.21 In the ohms reference circuit, a voltage divider supplies −10 volts (divider not shown) to the bases of transistors Q24 and Q25. Transistor Q24 is an emitter follower driving a voltage divider consisting of R81 and R82. This divider provides −10 volts and −1 volt (both referenced to common) for use in the ohms mode. Transistor Q25 is a current generator producing approximately 8 volts (referenced to the −25 volt supply line) across resistor R88. Variations in the −10 volts to the two transistor bases affect proportionally the −1 volt and −10 volt supplies and the −8 volt reference supplies thereby cancelling errors. The instrument can be considered to be operating in a ratio mode when measuring ohms.

4.22 The voltage reference (AC, DC, and BATT) consists of a selected I.C. transistor matrix (M4) and two transistors Q26 and Q27. The zener properties (reverse-biased emitter-base junction) of two of the matrix transistors are used as voltage references. One of the zeners is used to reference a current source which drives current generator Q26. The other zener is in series with two transistors (connected as diodes for temperature compensation) and is driven by the current from transistor Q26 to produce a stable voltage output of approximately 8 volts (referenced to the −25 volt supply line).

4.23 The current reference consists of a high gain amplifier (M6) and FET (Q29) interconnected for unity gain across R103. The current (I_R) through Q29 is set at 0.5 milliamps, as established by resistor R103.

4.24 NULL DETECTOR.

4.25 The null detector (figure 4.5) monitors the voltage across the integrating capacitor (C43) and generates a logic false signal when the voltage drops below a predetermined level. The null detector consists of an N-channel FET Q35, transistor Q33 and two stages of AND gate M7. A voltage divider consisting of R118 and R120 and filtered by C44, provides approximately −13 volts for the source of Q35 and one side of capacitor C43. Resistor R111 increases the gain and speed of the null detector by supplying positive feedback to the M7 input. Diode CR45 prevents the M7 input from going more negative than 0.7 volts.

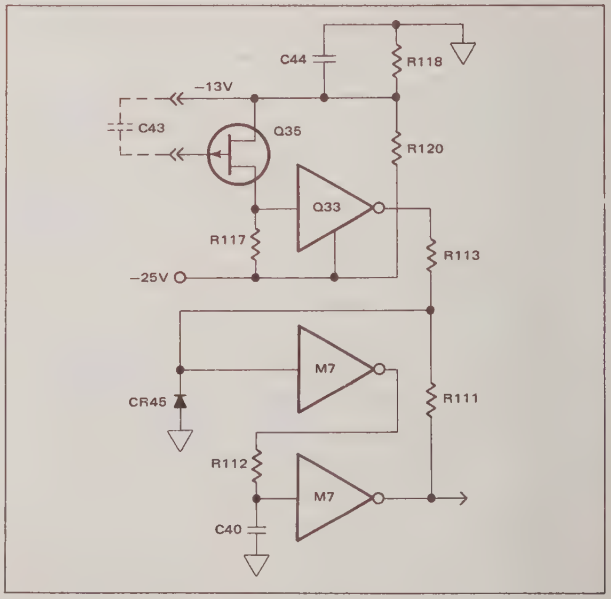


Figure 4.5 - Null Detector

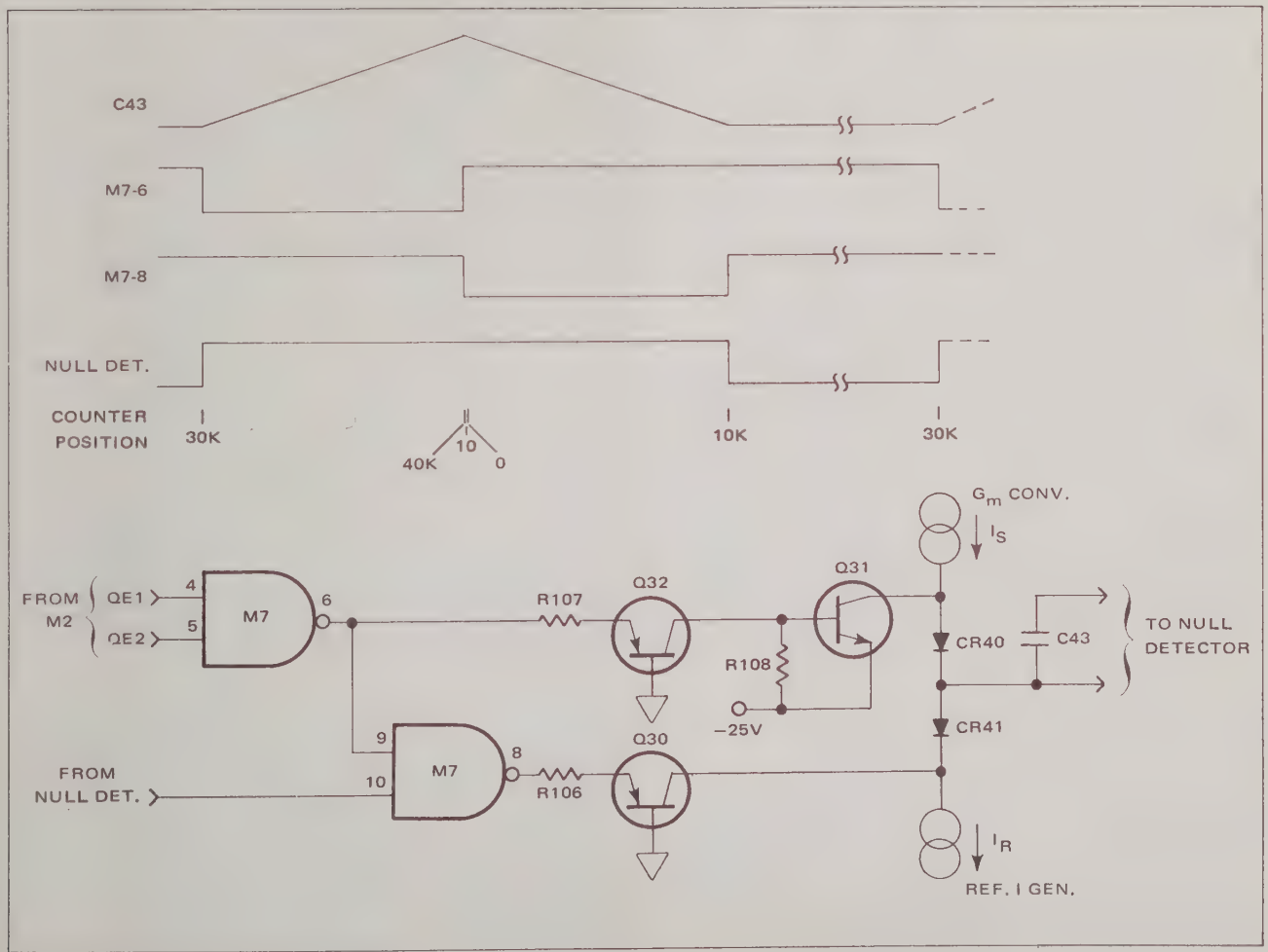


Figure 4.6 - Switch Logic/Integrator (Full Scale Input)

4.26 SWITCH LOGIC/INTEGRATOR.

4.27 The switch logic shown in figure 4.6 controls the flow of the currents from the G_m converter (I_S) and reference current generator (I_R) to integrator capacitor C43. During the signal integration period, the QE_1 and QE_2 outputs from the counter/multiplexer (M2) are both true causing M7-6 to be false. M7-8 is true, causing Q30 to turn on. This supplies the current to the reference current generator and back-biases CR41. With M7-6 false, transistors Q32 and Q31 are biased off and the current from the G_m converter flows through CR40 into C43, causing the capacitor to charge at a linear rate. At the completion of the signal integration period, QE_1 and QE_2 go false and M7-6 goes true. Transistors Q32 and Q31 are biased on, drawing all of the current from the G_m converter and back-biasing diode CR40. With the positive charge on C43, the null detector output to M7-10 is true and, with M7-6 true, sets M7-8 false which turns Q30 off. Current from C43 is now drawn by the reference current generator through diode CR41. When the voltage across C43 drops to its premeasurement level, the null detector output goes false, M7-8 goes true turning transistor Q30 back on, and no current flows into or out of C43.

4.28 CLOCK.

4.29 The clock, shown in figure 4.7, generates a 200 KHz signal used to drive the counter of the counter/multiplexer (M2). The counter is a free running multivibrator consisting of transistors Q23 and Q28. Diodes CR36 and CR37 and capacitor C37 insure start up by deriving the base bias from the collector outputs.

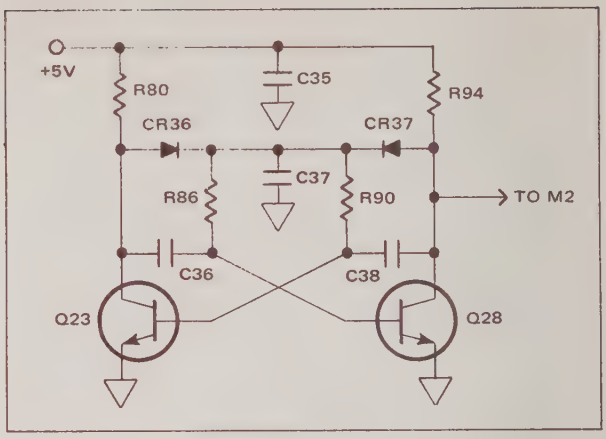


Figure 4.7 - Clock

4.30 COUNTER/MULTIPLEXER.

4.31 The counter/multiplexer (integrated circuit M2) is shown in the boxed area of figure 4.8. The unit, with inputs from the clock and null detector, generates the switch logic data (QE_1 and QE_2) as well as the multiplexed data for the display portion of the instrument.

4.32 The counter, consisting of four divide-by-ten counters, a divide-by-four counter and a ten-count pause circuit, runs continuously from the 200 KHz clock. The BCD outputs of the counters (A, B, C, D, and E) drive five four-bit latches which store the data at the end of a measurement cycle. When the counter reaches 30,000, outputs QE_1 and QE_2 are both true and the signal integration period begins. At 40,000, outputs QE_1 and QE_2 go false marking the end of the signal integration period and t

start of the reference integration period. The counter advances for ten more clock cycles (due to the ten-count pause circuit) and then overflows to 00000. The ten-count pause circuit operates in conjunction with the ten-digit offset current generator of the G_m converter to prevent switching transients from prematurely firing the null detector for inputs at or near zero.

4.33 The counter advances from 00000 until a false signal is generated by the null detector, signifying the end of the reference integration period. The null detector signal commands the latches to store the data received from the counters.

4.34 The multiplexer presents the BCD data sequentially from each of the five latches at the 1, 2, 4, 8 outputs, beginning with latch "A". The multiplexer is driven by a five-bit ring counter which is stepped at a 2 KHz rate by the ÷100 output of the counter. The five output lines of the ring counter (A, B, C, D, E) are brought out of the chip (M2) via the blanking control circuit (output A is not used).

4.35 Readout.

4.36 The readout circuits portion, shown in figure 4.9, consist of three numeric LED's, a 1K and polarity LED, a BCD-to-7 line converter and the display intensity control circuitry. The BCD data from the multiplexer is applied to the BCD/7-Line converter. The output of the converter is applied in parallel to the three numeric readout units. The readouts are enabled sequentially beginning with the 1's LED by the five-bit ring counter outputs (LED strobes).

4.37 DISPLAY INTENSITY CONTROL.

4.38 The display intensity control monitors the ambient light, by means of a light sensor (R1) on display board, and adjusts the output of the display units to optimize readability. The circuitry, shown in figure 4.10, is a one-shot, with the pulse width controlled by the impedance of the light sensor and the triggering supplied by the ÷100 counter output (2 KHz). The output of the circuit is fed to five gates controlling the ring counter output lines to the display units. The positive portion of the pulse inhibits a percentage of the LED strobe pulses. The higher the ambient light, the shorter the one-shot pulse duration and the brighter the display.

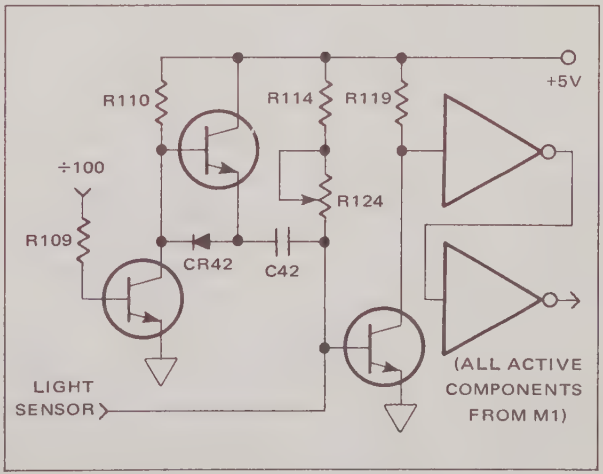


Figure 4.10 - Display Intensity Control

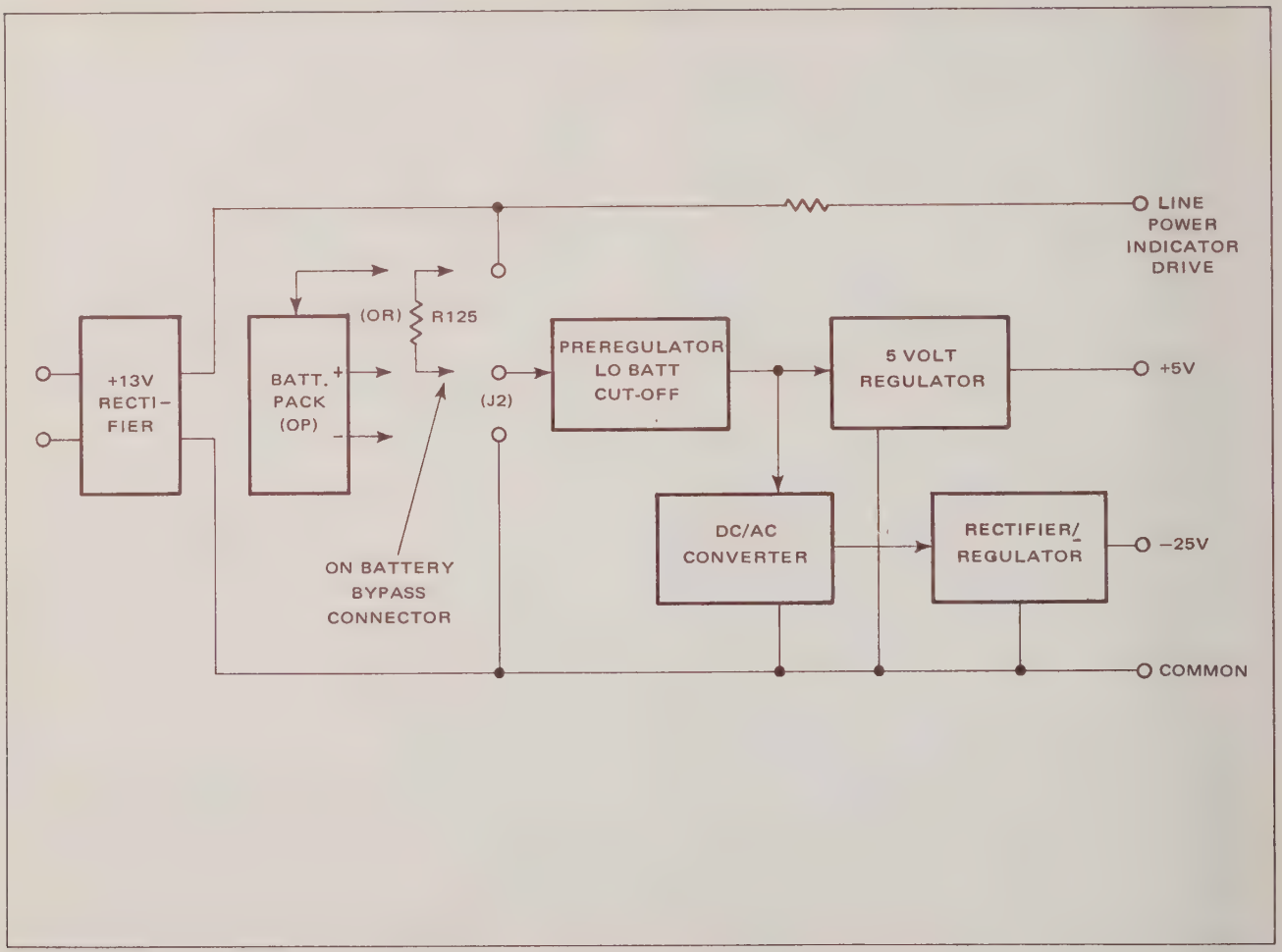


Figure 4.11 - Power Supply, Block Diagram

4.39 BLANKING CONTROL.

4.40 The blanking circuitry is contained in integrated circuit M2 and requires only that data be provided to indicate where blanking is to occur. The circuit causes all the displays to blank when the instrument is in an overload condition or causes the insignificant zeros to blank to the left of the decimal point for normal readings. The circuit operates by inhibiting the LED strobe lines. Decimal position data is provided by a wafer of the range switch selecting the appropriate LED strobe line. The overload data is furnished by the inverted QE_2L output of M2 (indicating a counter state of 20,000).

4.41 Power Supply.

4.42 The power supply, shown in block diagram of figure 4.11, consists of a +13 volt, full-wave, unregulated supply; a +6 volt preregulator and low battery cutoff circuit; a +5 volt regulator; a DC to AC converter driving a −25 volt rectifier/regulator circuit; and, when included, the battery pack.

4.43 13-VOLT SUPPLY.

4.44 The +13 volt power supply, along with the transformer and power input circuitry, is shown in figure 4.12. The +13 volts is derived from diodes CR16 and CR17 and filtered by C23. The 13 volts is applied through resistor R125 to the preregulator or (if equipped with the battery option) to the battery pack. The +13 volts is also applied through current limiting resistor R65 to the LINE power indicator on the front panel.

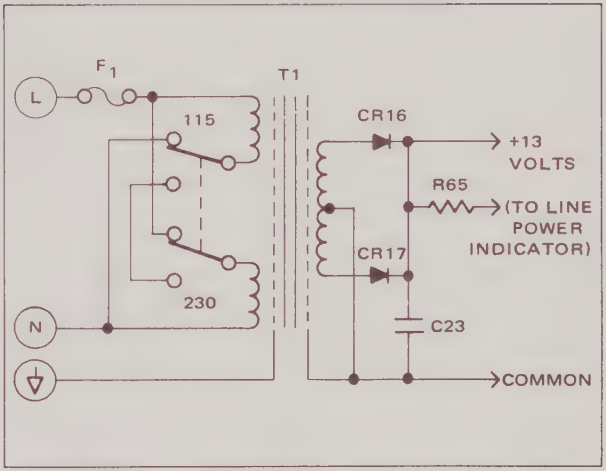


Figure 4.12 - +13 Volt Supply

4.45 PREREGULATOR (5 VA).

4.46 The preregulator circuit (figure 4.13) provides power to the readout board and the +5 volt and −25 volt supplies. With the instrument operating from line power (without battery pack), the circuit is connected to the +13 volt supply through the battery pack bypass (J2) and reduces the +13 volt level to a regulated level of approximately +6 volts. With the battery pack installed, the output of the preregulator generally approximates the voltage level of the battery pack. If the battery level drops below 5.5 volts, the preregulator disconnects the batteries from the remainder of the circuitry to prevent further battery drain.

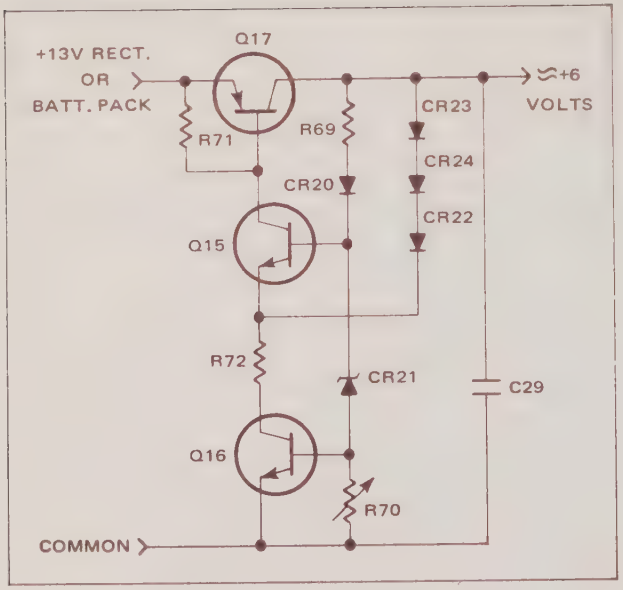


Figure 4.13 - Preregulator/Low Batt Cutoff

4.47 The circuit consists of a series regulator transistor (Q17) that is controlled by transistor Q15 referenced to zener CR21. Negative feedback for regulation is through diodes CR22, CR23, and CR24. When the input to the circuit drops below +5.5 volts, transistor Q16 cuts off and the preregulator output goes to zero.

4.48 FIVE-VOLT SUPPLY.

4.49 The five-volt regulator is shown in figure 4.14. Transistor Q20 is used as a series regulator with Q21 controlling the bias to Q20. Zener diode CR27, operating only at the initial start-up period, supplies current to the base of Q21, biasing Q20 on and supply current for the reference zener CR28. Negative feedback for regulation is through diodes CR33 and CR34. The base level of Q21 is set by potentiometer R75 to provide +5 volts output.

4.50 −25-VOLT SUPPLY.

4.51 The −25-volt supply (figure 4.15) consists of a transformer coupled push-pull oscillator operating at a frequency of approximately 10 KHz and a rectifier/regulator circuit. Starting bias for the power oscillator circuit is through R74. Diodes CR25 and CR26 limit the reverse bias across the base emitter junctions to 0.7 volts.

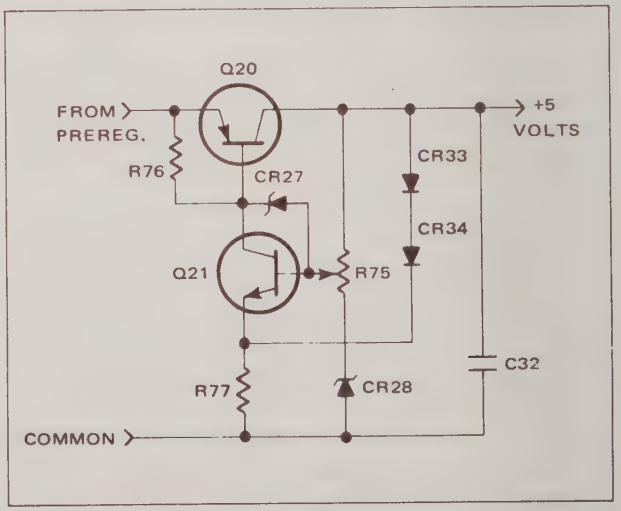


Figure 4.14 - +5 Volt Supply

4.52 The Rectifier/Regulator converts the square wave output from the secondary winding of the DC to AC Converter to negative dc through rectifier bridge CR29, CR30, CR31, and CR32 and filter capacitor C31. The – DC powers the –25V regulator consisting of transistor Q22. The regulator is a series emitter follower type with the reference supplied by zener CR35.

4.53 BATTERY PACK.

4.54 The battery pack consists of 5 rechargeable batteries, a fixed current charging unit and a thermal cutoff circuit (figure 4.16).

4.55 The batteries are nickel-cadmium 1.25 volt cells connected in series to provide about 6.25 volts. The cells

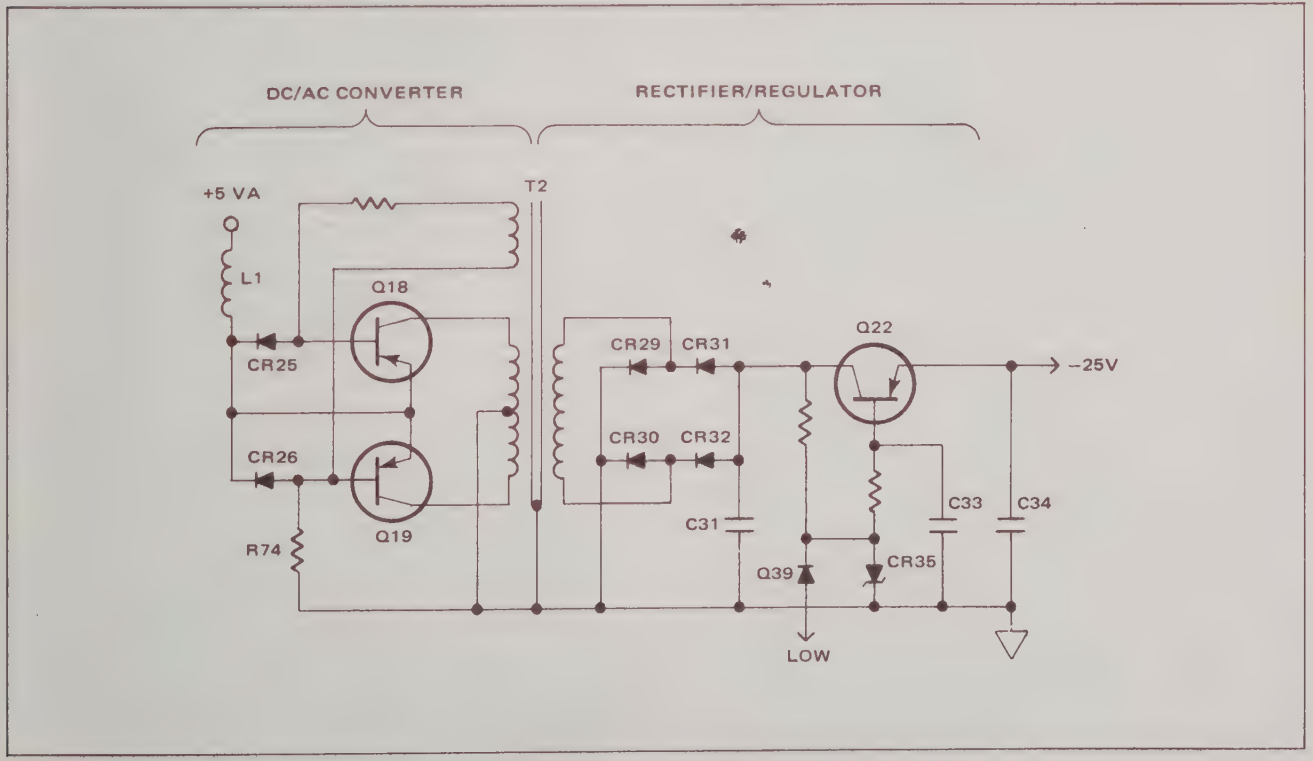


Figure 4.15 - –25V Supply

are charged by a constant current generator consisting of transistor Q2 and diodes CR5 and CR6. The generator supplies approximately 400 milliamps to the cells from the +13 volt supply with the DMM function switch set to OFF and about 800 milliamps with the function switch set to any other position. The amount of current is determined by Q2 emitter resistors R6, R7, R8, and R9. Diodes CR2, CR3, and CR4, positioned in close proximity to the power cells, provide the temperature sensing for the thermal cut-off circuit. The circuit consists of a bridge network supplied by a constant voltage source. The output of the bridge drives an operational amplifier (M1). The voltage source is made up of a constant current generator Q1 driving zener CR1 to provide +5.6 volts to the bridge. If the heat generated by the batteries due to charging reaches 60°, the voltage drop across the three diodes decreases sufficiently due to the temperature to cause the output of M1 to go positive. This removes the bias from transistor Q2 and current is prevented from flowing into the batteries.

4.56 SIGNAL FLOW.

4.57 Signal flow for each of the operating modes is described in Section 5, paragraph 5.22.

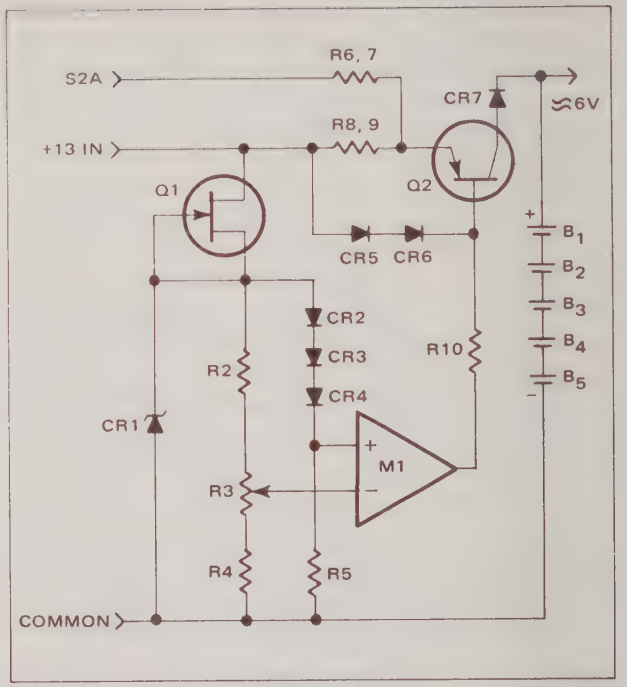


Figure 4.16 - Battery Pack.

5.1 DISASSEMBLY.

a. Loosen the two rear panel retaining screws (figure 5.1). Slide rear panel away from the chassis far enough to allow the top cover to be lifted and removed (figure 5.2). It is not necessary to remove the retaining screws entirely. Calibration points are now accessible on instruments without a battery pack. For instruments with battery pack, perform steps b and c.

b. Remove mounting screw on bottom of DMM (figure 5.3). Remove four mounting screws at top of battery pack. Without disconnecting battery pack connector P2, lift battery pack and place it behind the rear panel (figure 5.4). This provides access to all adjustments.

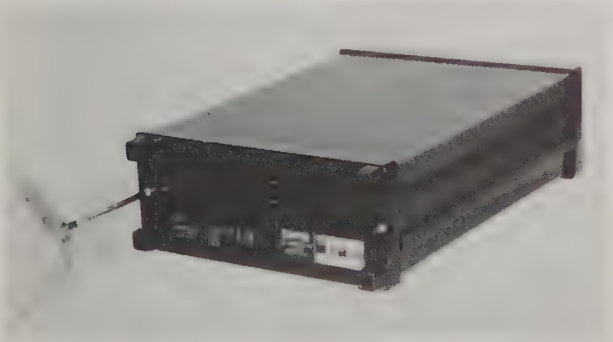


Figure 5.1 - Retaining Screw Removal

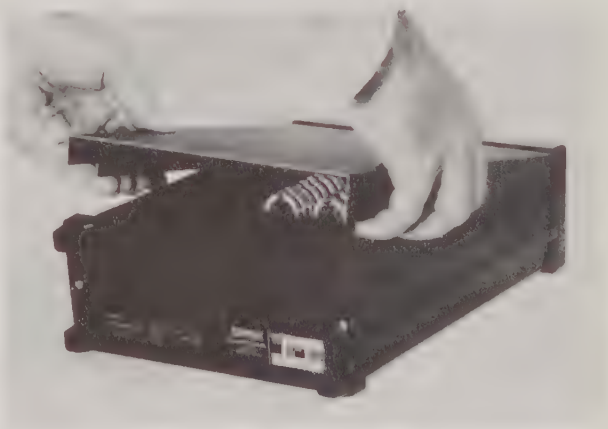


Figure 5.2 - Top Cover Removal

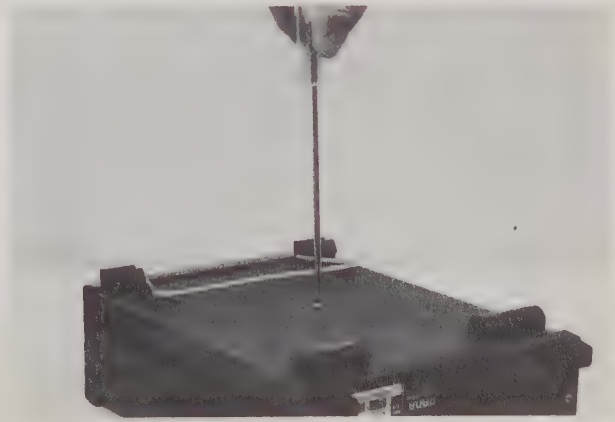


Figure 5.3 - Bottom Mounting Screw Removal

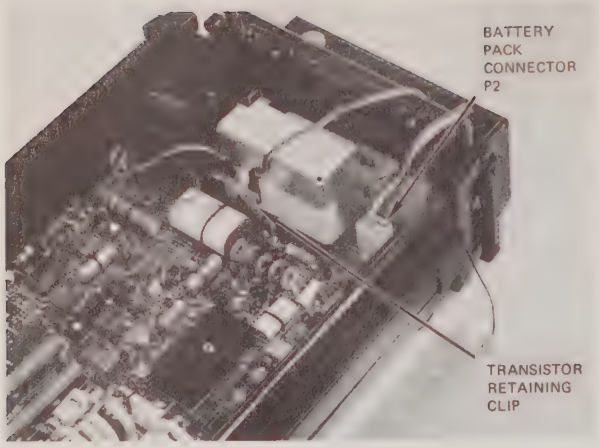


Figure 5.4 - Battery Pack Removed

Figure 5.5 - Battery Pack Disconnection

c. If desired, the battery pack can be removed completely: unplug P2; press downward on transistor retaining clip nearest P2 on rear panel to disconnect battery pack power transistor (figure 5.5). Calibration points are now accessible.

NOTE

To operate the instrument on line voltage with the battery pack removed, it is necessary to connect the battery bypass connector to J2. The bypass connector is stored on the battery pack (figure 2.3) when not in use.

5.2 To gain access to the soldered side of the printed circuit board for replacement of parts, the following additional step is necessary. This step is also required to remove the supporting front feet and tilt bail when installing the rack mounting flange or current shunt options.

a. With the instrument turned bottom-side-up and with the two rear panel retaining screws still loose, remove mounting screw on bottom of DMM (figure 5.3).

b. Slide the rear panel away from the chassis far enough to allow the bottom cover to be lifted and removed (figure 5.6). The soldered side of the board is now accessible.

Figure 5.6 - Bottom Cover Removal

5.3 REASSEMBLY.

5.4 The instrument is reassembled simply by reversing the above procedures. However, special attention must be given to reinstalling the battery pack (after bottom cover is replaced): install the four mounting screws at the top of the pack before installing the single mounting screw through the bottom cover.

5.5 When mounting the battery pack power transistor on rear panel, make sure that the gold-plated side of the transistor is placed adjacent to the insulating tape on the panel.

Table 5.1 - Replacement Batteries

Manu	P/N
Gould	4.0 SC
Marathon	S103
G. E.	XGCW4.0ST

5.6 BATTERY REPLACEMENT.

5.7 Table 5.1 is a chart listing recommended replacement batteries.

5.8 To replace batteries, follow the procedure below:

a. Perform disassembly procedure 5.1. Remove battery pack.

b. Remove six retaining screws holding plastic cover to battery pack p-c board. Remove plastic cover.

c. Unsolder pigtails from clips on battery terminals (figure 5.7). Remove batteries.

d. Install new batteries (with positive side toward components at edge of board).

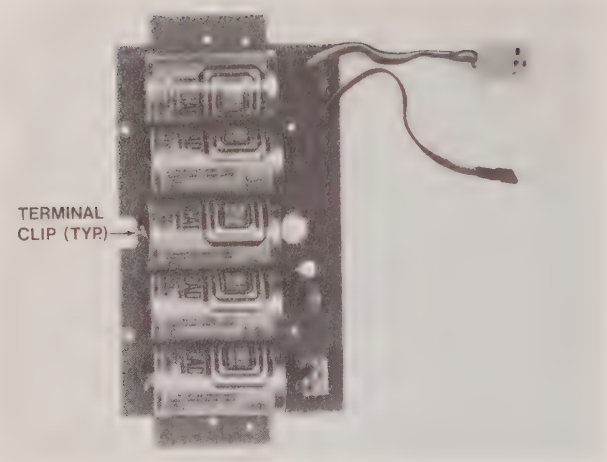


Figure 5.7

e. Solder pigtails onto terminal clips of new batteries.

f. Replace cover. Reinstall battery pack as described under "Battery Pack Installation", paragraph 2.9.

5.9 CALIBRATION.

5.10 This procedure is recommended to maintain the Model 3300 operating within its published specifications. An abbreviated form of this procedure is silkscreened under the DMM top cover.

5.11 Required Equipment.

5.12 The equipment required or acceptable substitutes are listed in Table 5.2.

5.13 Preparation.

5.14 Perform steps of disassembly procedure, paragraph 5.1. Apply Power to the DMM and allow 30 minutes for warmup time. Refer to figure 5.8 for location of adjustments.

5.15 DC Calibration.

a. Connect a jumper between the high and low input terminals. Connect a jumper across resistor R16. Select the DC function and the 100 mV range.

b. Connect the low input of the oscilloscope to "Mecca" and the high input to point A of resistor R36. Adjust potentiometer R47 for a display of zero ± 1 mV. Remove the oscilloscope leads.

c. Adjust the front panel OFFSET potentiometer R27 for zero with alternating plus and minus polarity indicators on the DMM readout. Remove the jumper from R16.

d. Connect the DMM low input to Mecca and the high input lead to point B of R18. Adjust R25 for a

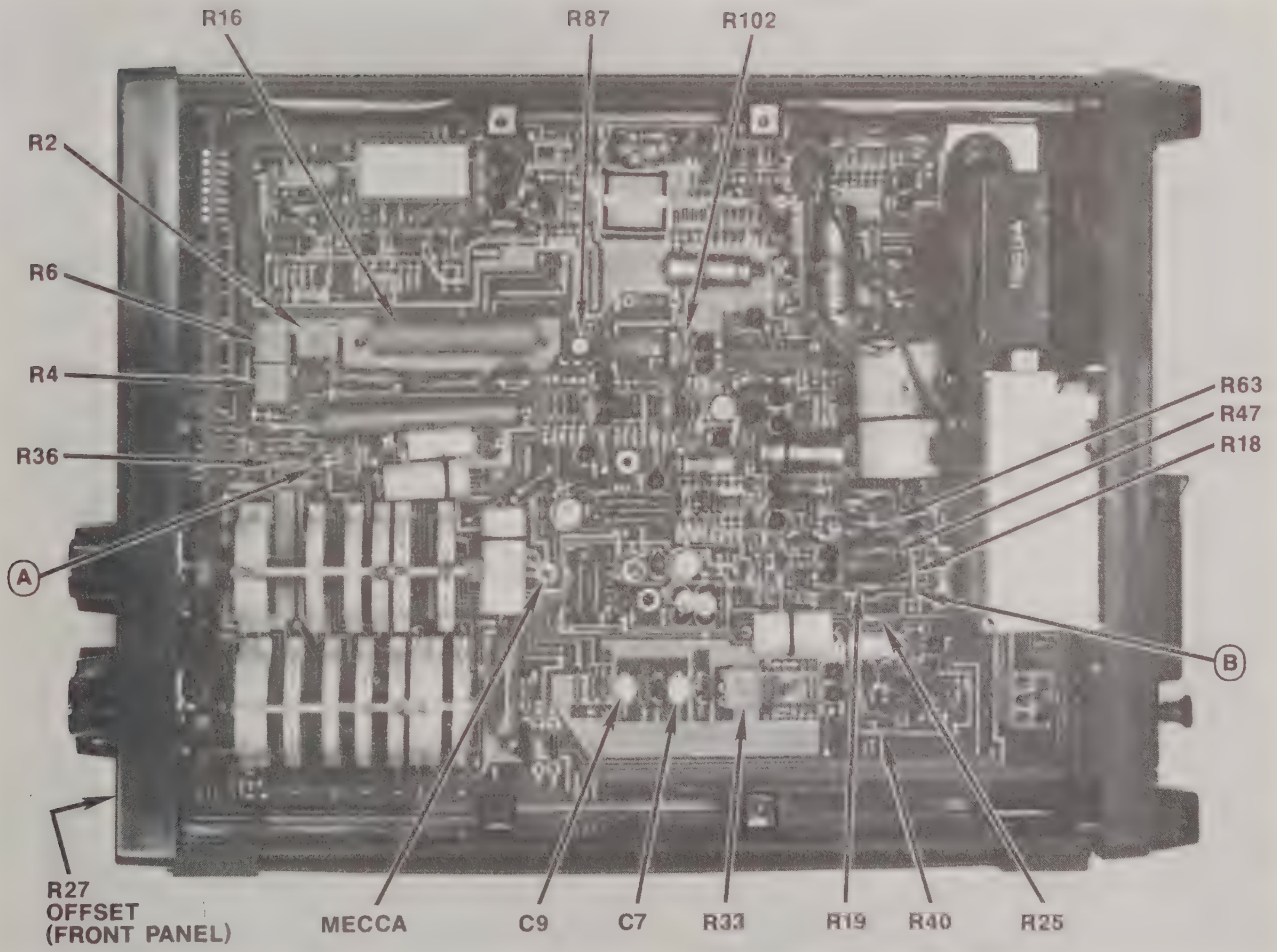


Figure 5.8 - Adjustment Locations

Table 5.2 - Calibration Equipment Required

Name	Use	Required Spec	Recommended Type
digital voltmeter	set "+" 480 mV	1 mV Resolution .1% accuracy	Dana 3800A
oscilloscope	isolator voltage zero isolator current zero AC Converter zero	at least 1 mV/Div sensitivity	Tektronix 503
DC Source	DC range calibration	6 place accuracy ± 1000V DC	COHU 326 or 351
ohms standard	K ohms calibration	.05%	ESI DB 62
AC Source	AC calibration	.05%	HP 745 & 746
insulated adjustment tool			JFD 5284
clipleads	approximately 12" long made with Mueller mini-gator clips & slip on isolators.		

DMM reading of +480 mV ± 20 mV. Remove the DMM leads. Remove the short on the input terminals and replace with a 1 Meg ohm resistor (5% 1/4W). Adjust R19 for zero readout and alternating plus and minus polarity indication. Remove the 1 megohm resistor and replace with a short and repeat step c.

e. Select the 1 volt range and remove the input short. Connect the DC source to the DMM and set the standard at +1 mV. Adjust R63 for a DMM readout of +0.001.

f. Select the ranges and set the DC source to the voltages indicated in Table 5.3 and adjust the indicated potentiometers for readouts equal to the input voltage.

g. Reduce the DC source voltage and remove input to the DMM.

Table 5.3 - DC Range Adjustments

Range	Input Voltage	Range Adjustment
1	+1.9000 VDC	R102
10	+19.000 VDC	R2
100	+190.00 VDC	R4
1000	+1000.0 VDC	R6

5.16 Resistance Calibration.

a. Select Kilohms function and the 100 range.

b. Connect a 190K ohm resistance standard to the DMM input terminals.

c. Adjust R87 for a DMM readout of 190.0.

d. Remove DMM input leads from the Kilohms standard.

Table 5.4 - AC Range Adjustments

Range	Input Voltage	Input Frequency	Range Adjustment
10	19.000	400 Hz	R33
10	19.000	15 KHz	C7
1	1.9000	15 KHz	C9

5.17 AC Calibration.

a. Select AC function and the 10 range.

b. Jumper the input terminals of the DMM and connect the oscilloscope low input to "Mecca" and the high input to wiper (center-terminal) of R40. Adjust R40 for a scope display of zero ± 500 mV.

c. Remove the oscilloscope leads and the jumper from the DMM input terminals.

d. Connect an AC standard to the DMM input terminals. Apply AC voltage inputs as shown in Table 5.4 and adjust the appropriate control for a DMM readout equal to the input voltage.

5.18 TROUBLESHOOTING.

5.19 The following procedure consists of a table listing possible instrument problems and a set of signal flow diagrams. The table indicates the circuit that could cause the malfunction, describes the normal output for the circuit, and indicates the paragraphs of the theory section that describe the circuit operation. The flow charts provide voltage levels, current levels and waveforms of the attenuator and G_m converter section for each function. The data provided on the charts, with the exception of the battery function, is for full scale input on the 10 range.

5.20 Procedure.

5.21 Check to be certain that the proper fuse and line voltage selector switch have been chosen and then perform the following steps:

a. Determine the exact nature and extent of the problem by performing the specification verification procedure (Section 3) and note which instrument operations fail to perform properly.

Table 5.5 - Troubleshooting

Symptom	Probable Cause	Circuit	Test Point	Signal	REFERENCE	
					Figure	Paragraph
DISPLAY BLANK	No Power	Power Supply	J2-2	+13V ± 50%	4.12	4.43
			Q17 Collector	+6.25 ± 12%	4.13	4.45
			CR33 Anode	+5V ± 5%	4.14	4.48
			C34 (–)	–25V ± 5%	4.15	4.50
	No Clock Pulse	Clock	M2-1	200 KHz Clock	4.7	4.29
	Counter Inoperative	M2	M2-16	200 mS Sq Wave	4.8	4.32
			M2-18	100 mS Sq Wave	4.8	4.32
			M2-11	2 KHz Signal	4.8	4.34
	Display Inhibited	Intensity Ckt	M1-11		4.10	4.38
OVERLOAD	Inverter Inoperative	Q34	M2-9	Logic True	4.8	4.40
DOES NOT ZERO	Insufficient Offset Current	Offset Generator	Q14	0.5 μA	4.3c	4.17
READING ERROR	I_S Error	G_m Converter			4.3	4.13
	I_R Error	I. Ref. Gen.		0.5 mA	4.4	4.19

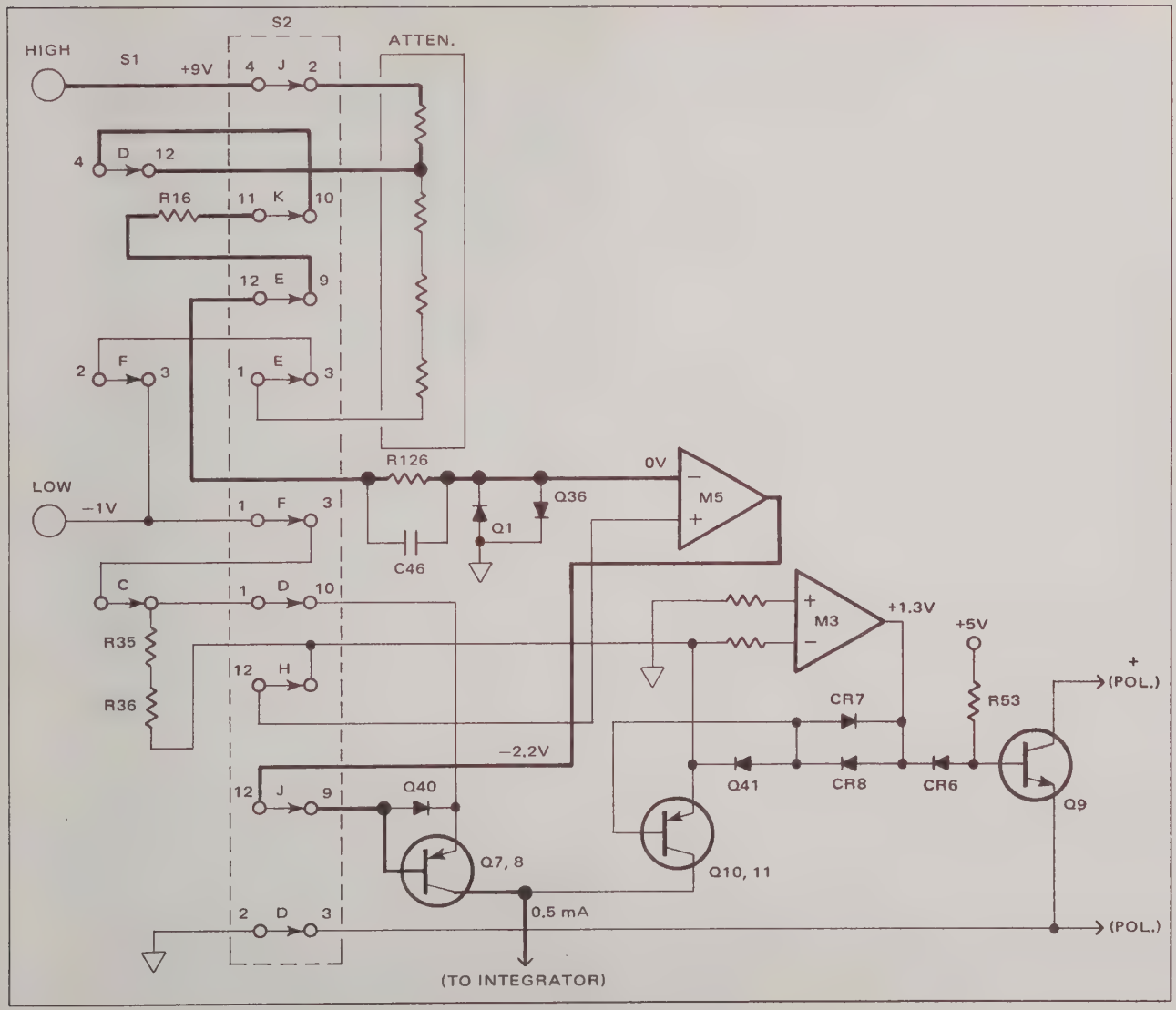


Figure 5.9 - DCV Mode, 10 Range

b. With power removed, perform the disassembly procedure described in paragraph 5.1.

c. Based on the information obtained in step a, refer to the symptoms of table 5.5. Select the symptoms that most nearly describe the problem observed and perform the appropriate troubleshooting operations.

5.22 Signal Flow.

5.23 Figures 5.9 through 5.12 and the following paragraphs cover the routing of the input signal through switches S1 (RANGE) and S2 (FUNCTION) and the major components for each Function mode. The heavy line of each drawing denotes the major signal path.

5.24 DCV FUNCTION.

5.25 The signal flow with the instrument in the DCV measurement mode for a positive input signal is shown in figure 5.9. The attenuator reduces a full scale input (+10 volts) to +1 volt for conversion by the G_m converter. With the positive input, the output of operational amplifier M3 is positive and transistor conducts, causing the plus polarity indicator to light.

5.26 ACV FUNCTION.

5.27 The signal routing for AC measurements is shown in figure 5.10. The input signal is fed through resistor R15 and capacitor C3 to a summing node at the inverting input of operational amplifier M5. The output of M5 drives a high output impedance amplifier (Q4, Q5, Q6) that drives rectifying diodes CR2 and CR3. The half-wave current flowing through the diodes is recombined across resistor R32. The resulting AC signal developed across R32 is fed through the AC attenuator to the summing node. The negative half wave voltage, developed across resistors R33, R34 is filtered through a pi network and fed to the non-inverting input of M3 for conversion to a proportional current (I_S).

5.28 KOHMS FUNCTION.

5.29 The signal routing for resistance measurement (10K range) is shown in figure 5.11. The negative 10 volts output from the OHMS reference is routed through the attenuator to draw 100 μA from the summing node at the inverting input of operational amplifier M5. The output of M5 goes positive, driving the LOW input terminal positive and supplying positive current through the resistance being measured (R_X) to the summing node. The circuit stabilizes when the current through the resistor (R_X) equals the reference current (100 μA). The voltage developed across R_X is converted by M3 to a proportional current (I_S).

5.30 BATTERY FUNCTION.

5.31 The signal flow for the battery measurement function is shown in figure 5.12. The operational amplifier M5 and the normal current determining resistor (R35 and R36) are switched to analog common. The battery voltage is converted into a proportional current through R1 (located on the battery pack) and fed to operational amplifier M3 to generate I_S.

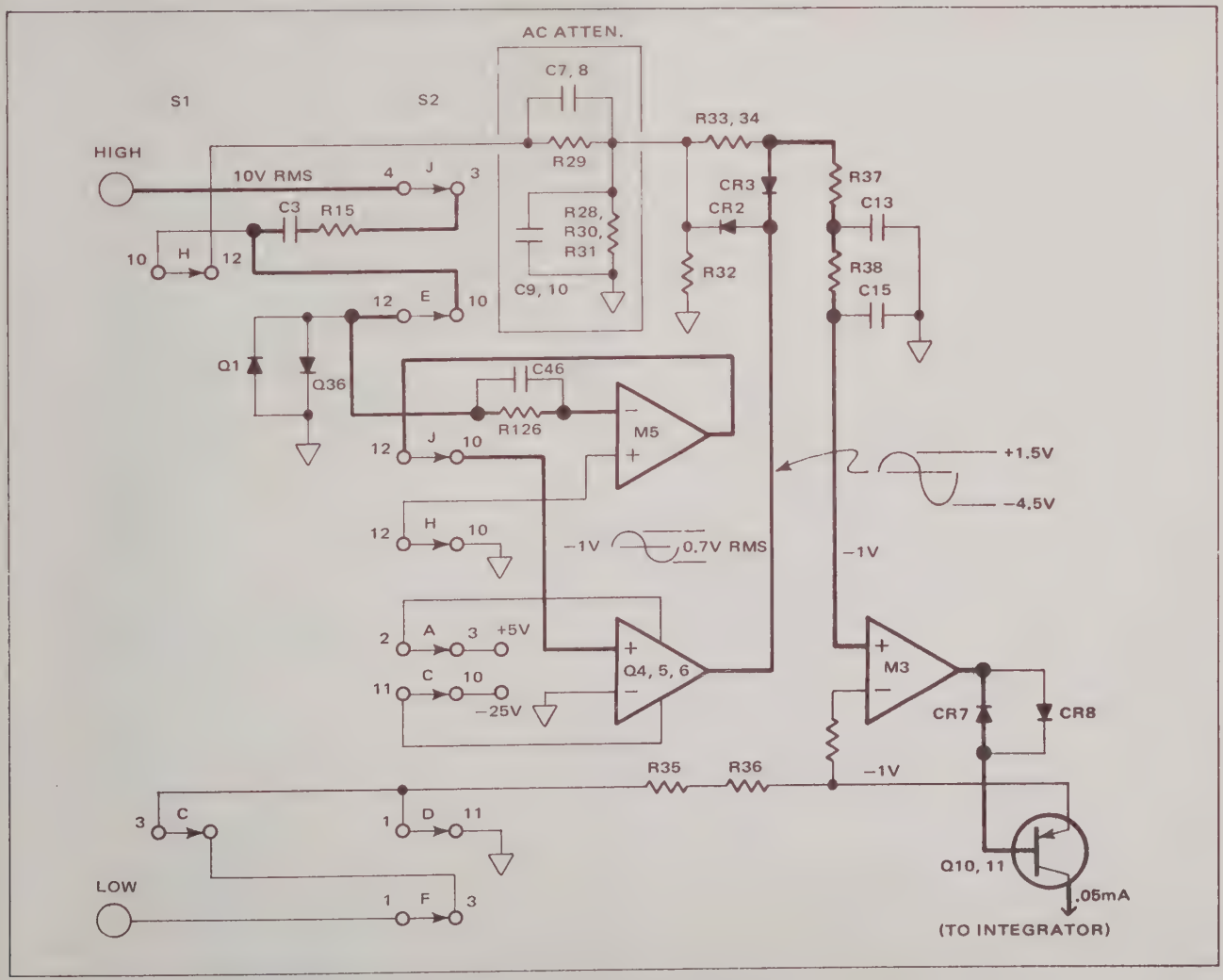


Figure 5.10 - ACV Mode, 10 Range

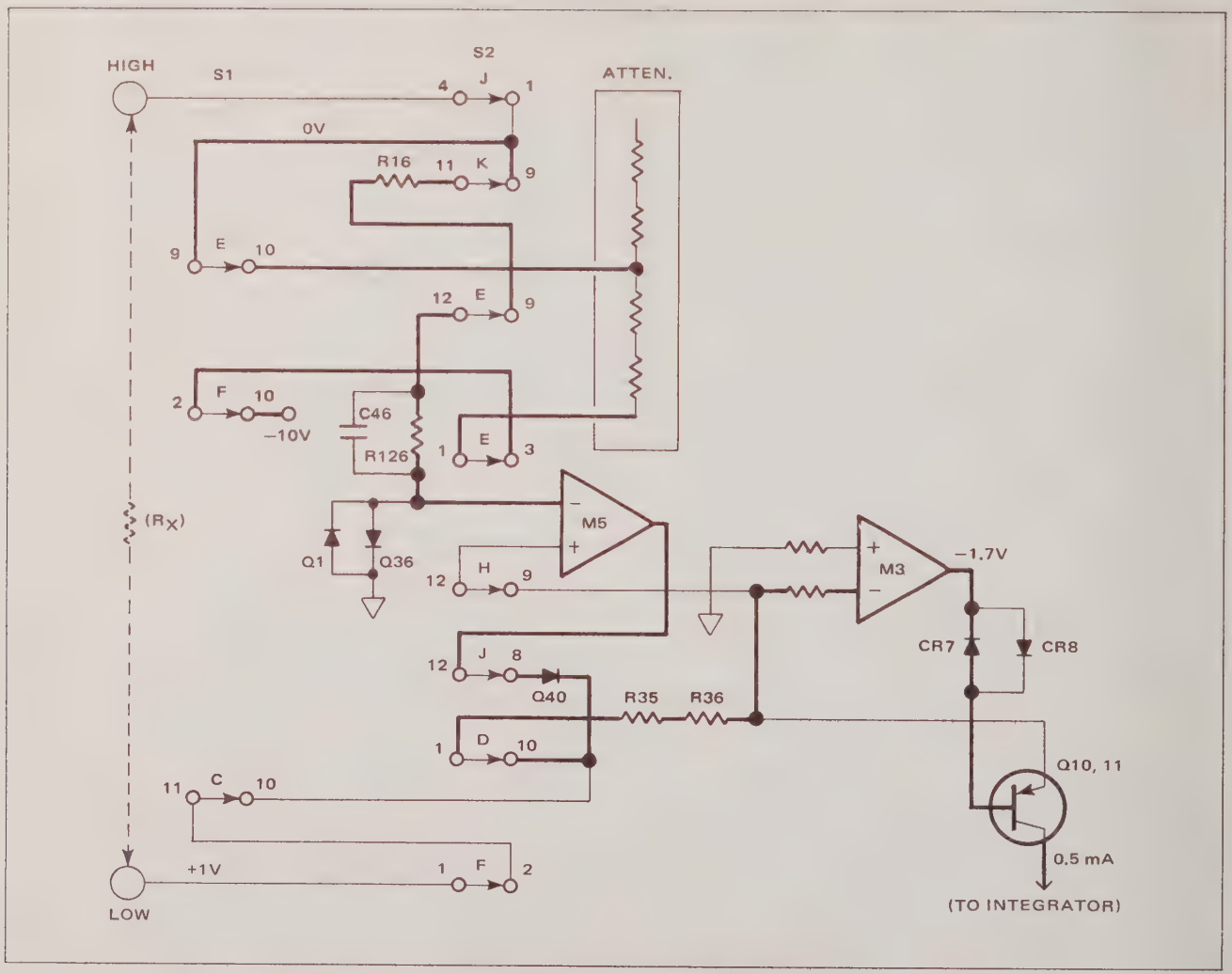


Figure 5.11 - KOHMS Mode, 10 Range

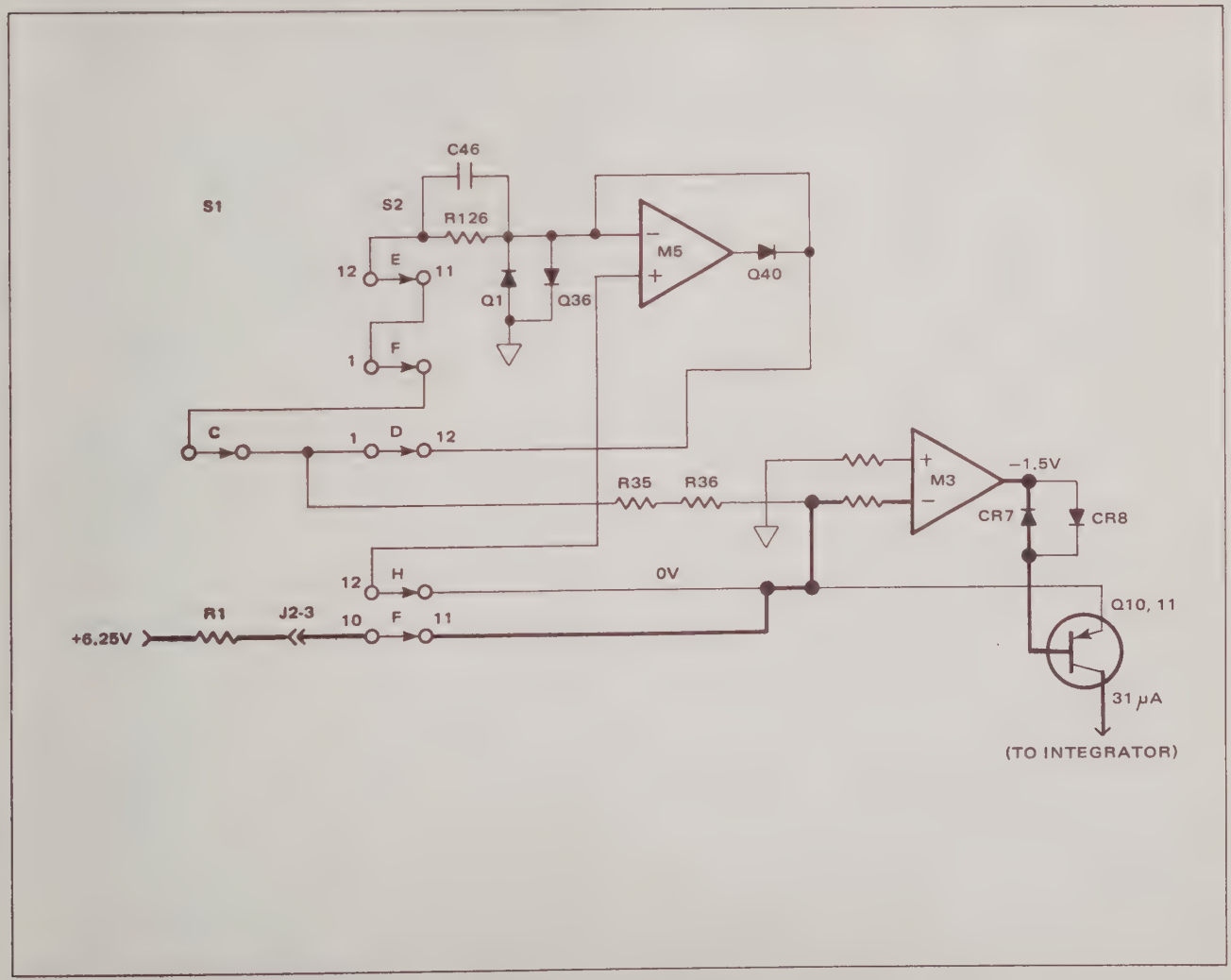
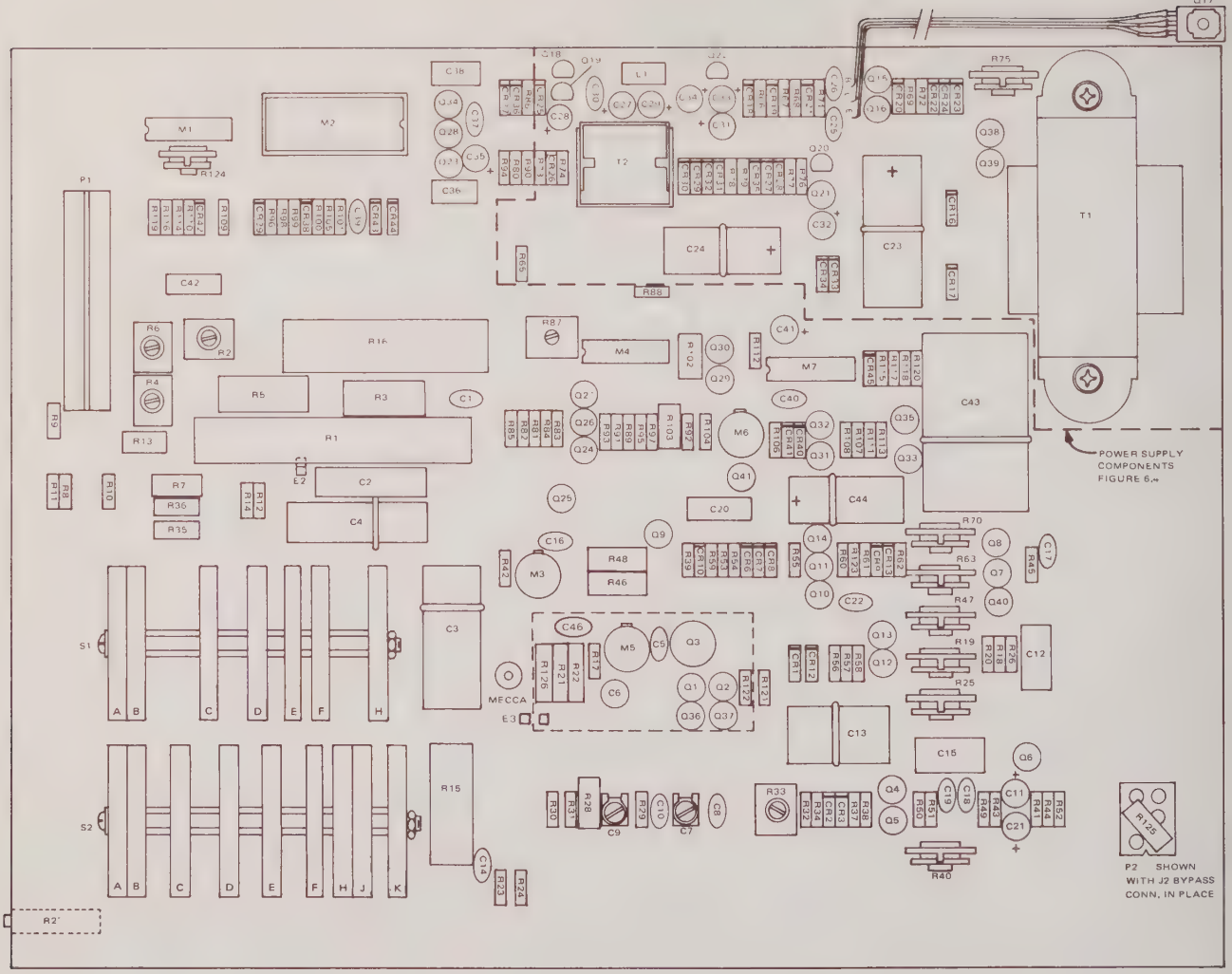


Figure 5.12 - Battery Mode

SECTION 6 SCHEMATICS

Figure	Title	Page
6.1	Main PC Board	6-2/6-3
6.2	Readout	6-4/6-5
6.3	Battery Pack	6-6/6-7
6.4	Power Supply	6-9


POWER SUPPLY COMPONENTS FIGURE 6.
P2 SHOWN WITH J2 BYPASS CONN. IN PLACE
MECCA
A B C D E F H
A B C D E F H J K

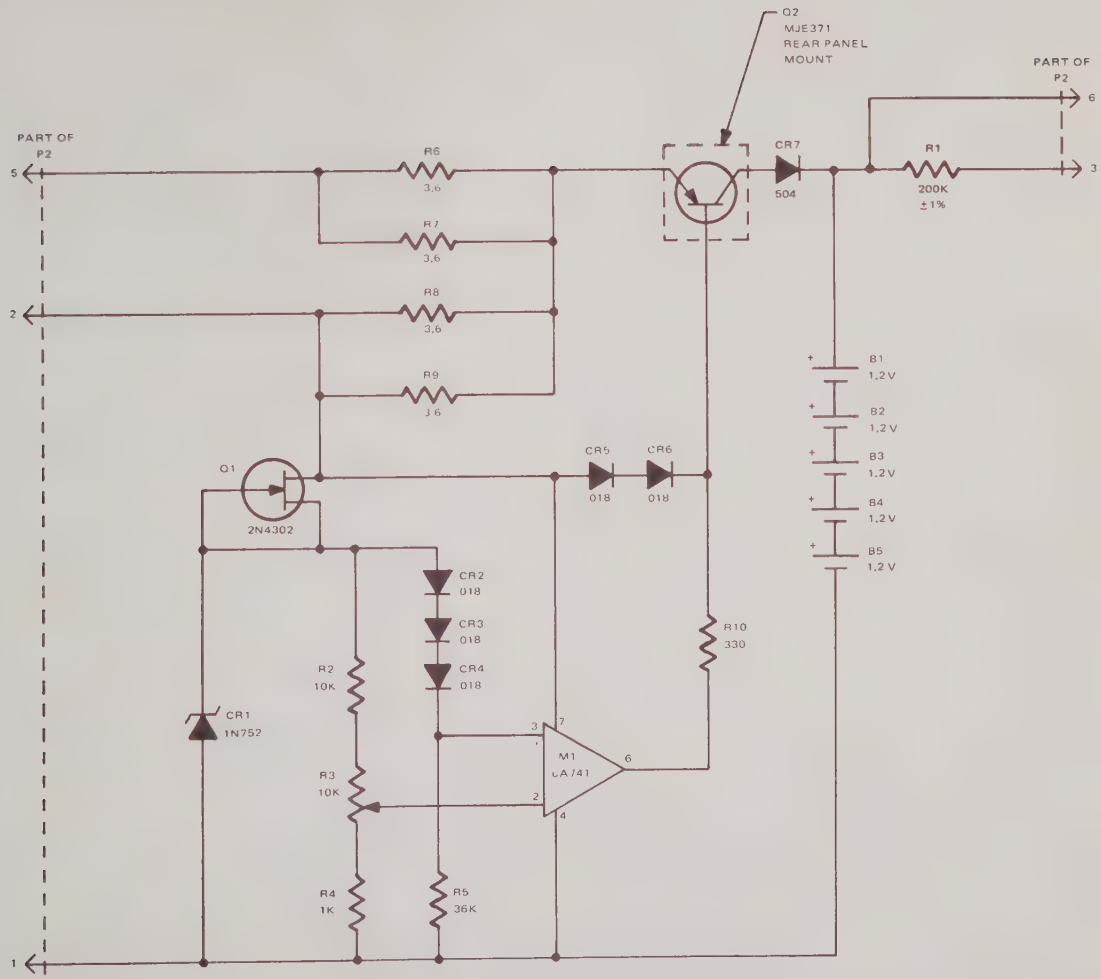


Figure 6.3 - Battery Pack 6-7

SECTION 7 PARTS LIST

7.1 This section contains lists of replaceable parts arranged by major assemblies: Battery Pack, Readout, and Main PC Board.

7.2 The following manufacturer's code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1, H4-2, and their supplements.

LIST OF SUPPLIERS

FSC	NAME
01121	ALLEN BRADLEY CO. MILWAUKEE, WISCONSIN
01295	TEXAS INSTRUMENTS, INC. (Components Group) DALLAS, TEXAS
03888	PYROFILM CORP. WHIPPANY, NEW JERSEY
04713	MOTOROLA, INC. (Semiconductor Products Division) PHOENIX, ARIZONA
05397	UNION CARBIDE CORP. (Materials Systems Division) CLEVELAND, OHIO
07263	FAIRCHILD SEMICONDUCTOR (Division of Fairchild Camera & Instrument Corp.) MOUNTAIN VIEW, CALIFORNIA
09023	CORNELL-DUBILIER ELECTRONICS (Division Federal Pacific Electric Co.) SANFORD, NORTH CAROLINA
11237	CTS KEENE, INC. PASO ROBLES, CALIFORNIA
12060	DIODES, INC. CHATSWORTH, CALIFORNIA
18178	VACTEC, INC. MARYLAND HEIGHTS, MISSOURI
21793	DANA LABORATORIES, INC. IRVINE, CALIFORNIA
22045	JORDAN ELECTRIC CO. VAN NUYS, CALIFORNIA
27556	IMB ELECTRONIC PRODUCTS, INC. SANTA FE SPRINGS, CALIFORNIA
31741	GOULD-NATIONAL BATTERIES ST. PAUL, MINNESOTA
56289	SPRAGUE ELECTRIC CO (Pacific Division) LOS ANGELES, CALIFORNIA
71468	ITT CANNON ELECTRIC SANTA ANA, CALIFORNIA
71471	AEROVOX CORP. (Cinema Plant) MONCKS CORNER, SOUTH CAROLINA
71590	CENTRALAB ELECTRONICS (Division of Globe-Union, Inc.) MILWAUKEE, WISCONSIN
73138	BECKMAN INSTRUMENTS, INC. (Helipot Division) FULLERTON, CALIFORNIA
73445	AMPEREX ELECTRONIC CORP. HICKSVILLE, LONG ISLAND, NEW YORK
80131	ELECTRONIC INDUSTRIES ASSOC. WASHINGTON, D. C.
80294	BOURNS, INC. RIVERSIDE, CALIFORNIA
81160	FOSTER TRANSFORMER CO. CINCINNATI, OHIO
81349	MILITARY SPECIFICATION
99800	AMERICAN PRECISION INDUSTRIES, INC. (Delevan Division) EAST AURORA, NEW YORK

403646 – Assy., PCB, BATTERY PACK OPTION

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
B1	920643	BATTERY			1.20V		31741	4.0SCL D Size
B2	920643	BATTERY			1.20V		31741	4.0SCL D Size
B3	920643	BATTERY			1.20V		31741	4.0SCL D Size
B4	920643	BATTERY			1.20V		31741	4.0SCL D Size
B5	920643	BATTERY			1.20V		31741	4.0SCL D Size
CR1	220019	DIODE	SILICO	ZENER	1N752A		04713	1N752A
CR2	211083	DIODE	SILICO		018		21793	211083
CR3	211083	DIODE	SILICO		018		21793	211083
CR4	211083	DIODE	SILICO		018		21793	211083
CR5	211083	DIODE	SILICO		018		21793	211083
CR6	211083	DIODE	SILICO		018		21793	211083
CR7	210004	DIODE	SILICO		SD4		12060	SD4
M1	230119	INTEGRATED CIRCUIT		8 PIN	UA741		07263	UA741
Q1	200107	TRANS	N-CHAN	FIELD EFFECT			01295	2N4302
Q2	200183	TRANS	SILICO	PNP	MJE371		04713	MJE371
R1	010618	RES	METAL	200 K		.25%	81349	RN55C
R2	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R3	040217	RES	POT	10 K		20%	11237	X201
R4	000513	RES	CARBON	51 K		5% 1/4W	81349	RC07GF513J
R5	000363	RES	CARBON	36 K		5% 1/4W	81349	RC07GF363J
R6	001733	RES	CARBON	3.6 OHM		5% 1/4W	01121	

403646 – Assy., PCB, BATTERY PACK OPTION *continued*

REF DES	DANA P/N	DESCRIPTION				FSC	MANU P/N
R7	001733	RES	CARBON	3.6 OHM	5% 1/4W	01121	
R8	001733	RES	CARBON	3.6 OHM	5% 1/4W	01121	
R9	001733	RES	CARBON	3.6 OHM	5% 1/4W	01121	
R10	000331	RES	CARBON	330 OHM	5% 1/4W	81349	RC07GF331J

NOTE

A satisfactory replacement for special Dana diode 018 is TI 1N4448.

403668 – Assy., PCB, READOUT

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
C1	110151	CAP 10 MFD 25 V	71468	4321216210
C2	100017	CAP CERAM .01 MFD 100 V 20%	56289	TG-S10
C3	100017	CAP CERAM .01 MFD 100 V 20%	56289	TG-S10
CR1	210045	L.E.D. RED LITE 2	Lytronics	RED LITE 2
CR2	210045	L.E.D. RED LITE 2	Lytronics	RED LITE 2
LED 1	210044	L.E.D. DISPLAY ± 1	Lytronics	DL-101A
LED 2	210043	L.E.D. DISPLAY 0-9	Lytronics	DL-10A
LED 3	210043	L.E.D. DISPLAY 0-9	Lytronics	DL-10A
LED 4	210043	L.E.D. DISPLAY 0-9	Lytronics	DL-10A
M1	230132	INTEGRATED CIRCUIT SN7447N	01295	SN7447N
M2	230125	INTEGRATED CIRCUIT CA3086	21793	230125
Q2	200184	TRANS MPSA55	04713	MPSA55
Q3	200184	TRANS MPSA55	04713	MPSA55
Q4	200184	TRANS MPSA55	04713	MPSA55
Q5	200184	TRANS MPSA55	04713	MPSA55
Q6	200037	TRANS SILICO NPN 2N3646	80131	2N3646
R1	920639	PHOTO CELL LIGHT SENSOR	18178	VT904

403668 – Assy., PCB, READOUT *continued*

RLF DES	DANA P/N	DESCRIPTION				FSC	MANU P/N
R4	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R5	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R6	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R7	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R8	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R9	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R10	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R11	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R12	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R13	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R14	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R15	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R16	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R17	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R18	000302	RES	CARBON	3 K	5% 1/4W	81349	RC07GF302J
R19	000102	RES	CARBON	1 K	5% 1/4W	81349	RC07GF102J
R20	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R21	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R22	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R23	000750	RES	CARBON	75 OHM	5% 1/4W	81349	RC07GF750J
R24	000201	RES	CARBON	200 OHM	5% 1/4W	81349	RC07GF201J
R25	000512	RES	CARBON	5.1 K	5% 1/4W	81349	RC07GF512J

403669 – Assy., MAIN PC BOARD

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
C1	100071	CAP	DISC	.001 MFD	1000 V	20%	56289	5GA-D10
C2	120283	CAP	POLY	.03 MFD	50 V	20%	27556	PA2A303
C3	120280	CAP	MYLAR	.22 MFD	1000 V		27556	ZA2J224K
C4	120282	CAP	POLY	.27 MFD	50 V	20%	27556	PA2A274
C5	100075	CAP	CERAM	10 PFD	1 KV		56289	10TCCQ10
C6	110126	CAP	TANTA	6.8 MFD	35 V		71468	431217168
C7	130077	CAP		1.8 PFD	500 V		73445	2222-809-05002
C8	100075	CAP	CERAM	10 PFD	1 KV		56289	10TCCQ10
C9	130077	CAP		1.8 PFD	500 V		73445	2222-809-05002
C10	100060	CAP			10TCCQ15		56289	10TCCQ15
C11	110126	CAP	TANTA	6.8 MFD	35 V		71468	431217168
C12	121091	CAP	MYLAR	.033 MFD	100 V	10%	09023	WMF1533
C13	120266	CAP	MYLAR	2 MFD	50 V	5%	27556	XA2A205J
C14	100075	CAP	CERAM	10 PFD	1 KV		56289	10TCCQ10
C15	120026	CAP	MYLAR	.47 MFD	100 V	10%	27556	AS2B474K
C16	100076	CAP		20 PFD	1 KV		56289	10TCCQ20
C17	101174	CAP	CERAM	.001 MFD	500 V	10%	71471	SCD3X5F
C18	100017	CAP	CERAM	.01 MFD	100 V	20%	56289	TG-S10
C19	100017	CAP	CERAM	.01 MFD	100 V	20%	56289	TG-S10
C20	121091	CAP	MYLAR	.033 MFD	100 V	10%	09023	WMF1533
C21	110151	CAP		10 MFD	25 V		71468	4321216210
C22	101174	CAP	CERAM	.001 MFD	500 V	10%	71471	SCD3X5F
C23	110157	CAP	ELECT	470 MFD	25 V		73445	ET471K025A01
C24	111148	CAP	ELECT	100 MFD	25 V	20%	56289	TE1211
C25	100017	CAP	CERAM	.01 MFD	100 V	20%	56289	TG-S10

403669 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
C26	100017	CAP	CERAM	.01 MFD	100 V	20%	56289	TG-S10
C27	110159	CAP	TANTA	33 MFD	10 V	10%	05397	K33E10
C28	110159	CAP	TANTA	33 MFD	10 V	10%	05397	K33E10
C29	110159	CAP	TANTA	33 MFD	10 V	10%	05397	K33E10
C30	100017	CAP	CERAM	.01 MFD	100 V	20%	56289	TG-S10
C31	110158	CAP	TANTA	10 MFD	50 V	10%	05397	K10E50
C32	110140	CAP	TANTA	47 MFD	6.3 V		71468	4321212247
C33	110126	CAP	TANTA	6.8 MFD	35 V		71468	431217168
C34	110126	CAP	TANTA	6.8 MFD	35 V		71468	431217168
C35	110140	CAP	TANTA	47 MFD	6.3 V		71468	4321212247
C36	120034	CAP	POLY	100 PFD	600 V	5%	71590	CPR-100J
C37	100017	CAP	CERAM	.01 MFD	100 V	20%	56289	TG-S10
C38	120034	CAP	POLY	100 PFD	600 V	5%	71590	CPR-100J
C39	100030	CAP	DISC	29 PFD	500 V	10%	71471	N-150
C40	101174	CAP	CERAM	.001 MFD	500 V	10%	71471	SCD3X5F
C41	110151	CAP		10 MFD	25 V		71468	4321216210
C42	121088	CAP	MYLAR	.01 MFD	100 V	10%	09023	WMF1S1
C43	120281	CAP	MYLAR	10 MFD	50 V		27556	YA2911K
C44	111148	CAP	ELECT	100 MFD	25 V	20%	56289	TE1211
C46	101145	CAP	DISC	100 PFD	500 V	10%	71471	N-150
C47	110143	CAP	TANTA	1 MFD	35 V		05397	K1E35
CR1	220022	DIODE	SILICO	ZENER	1N965B		04713	1N965B
CR2	211083	DIODE	SILICO		018		21793	211083
CR3	211083	DIODE	SILICO		018		21793	211083
CR6	211083	DIODE	SILICO		018		21793	211083
CR7	211083	DIODE	SILICO		018		21793	211083

403669 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION	FSC	MANU P/N
CR8	211083	DIODE SILICO 018	21793	211083
CR9	211083	DIODE SILICO 018	21793	211083
CR10	211083	DIODE SILICO 018	21793	211083
CR12	211083	DIODE SILICO 018	21793	211083
CR13	220031	DIODE SILICO ZENER 1/4M3.3AZ5	04713	1/4M3.3AZ5
CR16	210004	DIODE SILICO 1N4004	81349	1N4004
CR17	210004	DIODE SILICO 1N4004	81349	1N4004
CR18	220027	DIODE SILICO ZENER 1N749A	04713	1N749A
CR19	211083	DIODE SILICO 018	21793	211083
CR20	211083	DIODE SILICO 018	21793	211083
CR21	220027	DIODE SILICO ZENER 1N749A	04713	1N749A
CR22	211083	DIODE SILICO 018	21793	211083
CR23	211083	DIODE SILICO 018	21793	211083
CR24	211083	DIODE SILICO 018	21793	211083
CR25	211083	DIODE SILICO 018	21793	211083
CR26	211083	DIODE SILICO 018	21793	211083
CR27	220027	DIODE SILICO ZENER 1N749A	04713	1N749A
CR28	220027	DIODE SILICO ZENER 1N749A	04713	1N749A
CR29	211083	DIODE SILICO 018	21793	211083
CR30	211083	DIODE SILICO 018	21793	211083
CR31	211083	DIODE SILICO 018	21793	211083
CR32	211083	DIODE SILICO 018	21793	211083
CR33	211083	DIODE SILICO 018	21793	211083
CR34	211083	DIODE SILICO 018	21793	211083
CR35	220064	DIODE ZENER 27 V 2%	04713	.4M27Z2

403669 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
CR36	211083	DIODE	SILICO		018		21793	211083
CR37	211083	DIODE	SILICO		018		21793	211083
CR38	220022	DIODE	SILICO	ZENER	1N965B		04713	1N965B
CR39	211083	DIODE	SILICO		018		21793	211083
CR40	210036	DIODE	SILICO		FD300		07263	FD300
CR41	210036	DIODE	SILICO		FD300		07263	FD300
CR42	211083	DIODE	SILICO		018		21793	211083
CR43	211083	DIODE	SILICO		018		21793	211083
CR44	211083	DIODE	SILICO		018		21793	211083
CR45	211083	DIODE	SILICO		018		21793	211083
L1	310106	CHOKE	INDUCTOR	10 UH		10%	99800	1537-36
M1	230125	INTEGRATED CIRCUIT			CA3086		21793	230125
M2	230120	INTEGRATED CIRCUIT		24 PIN	3814		07263	3814
M3	230110	INTEGRATED CIRCUIT		8 PIN	LM301A		07263	LM301A
M4	230124	INTEGRATED CIRCUIT		NPN	CA3086		21793	230124
M5	230123	INTEGRATED CIRCUIT		SELECTED	UA777		21793	230123
M6	230119	INTEGRATED CIRCUIT		8 PIN	UA741		07263	UA741
M7	230076	INTEGRATED CIRCUIT			SN74L00N		01295	SN74L00N
Q1	200095	TRANS			2N3563		07263	2N3563
Q2	200048	TRANS	SILICO	NPN	2N3565		80131	2N3565
Q3	201084	TRANS	GERMAN	PNP	2N1304		01295	2N1304
Q4	200088	TRANS	SILICO	PNP	2N4248		80131	2N4248

403669 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION				FSC	MANU P/N
Q5	200043	TRANS	SILICO	NPN	2N3565	80131	2N3565
Q6	200088	TRANS	SILICO	PNP	2N4248	80131	2N4248
Q7	200068	TRANS			2N4250	80131	2N4250
Q8	200068	TRANS			2N4250	80131	2N4250
Q9	200037	TRANS	SILICO	NPN	2N3646	80131	2N3646
Q10	200068	TRANS			2N4250	80131	2N4250
Q11	200068	TRANS			2N4250	80131	2N4250
Q12	200068	TRANS			2N4250	80131	2N4250
Q13	200043	TRANS	SILICO	NPN	2N3565	80131	2N3565
Q14	200088	TRANS	SILICO	PNP	2N4248	80131	2N4248
Q15	200037	TRANS	SILICO	NPN	2N3646	80131	2N3646
Q16	200037	TRANS	SILICO	NPN	2N3646	80131	2N3646
Q17	200183	TRANS	SILICO	PNP	MJE371	04713	MJE371
Q18	200184	TRANS			MPSA55	04713	MPSA55
Q19	200184	TRANS			MPSA55	04713	MPSA55
Q20	200184	TRANS			MPSA55	04713	MPSA55
Q21	200043	TRANS	SILICO	NPN	2N3565	80131	2N3565
Q22	200184	TRANS			MPSA55	04713	MPSA55
Q23	200037	TRANS	SILICO	NPN	2N3646	80131	2N3646
Q24	200088	TRANS	SILICO	PNP	2N4248	80131	2N4248
Q25	200088	TRANS	SILICO	PNP	2N4248	80131	2N4248
Q26	200088	TRANS	SILICO	PNP	2N4248	80131	2N4248
Q27	200088	TRANS	SILICO	PNP	2N4248	80131	2N4248
Q28	200037	TRANS	SILICO	NPN	2N3646	80131	2N3646
Q29	200107	TRANS	N-CHAN	FIELD EFFECT		80131	2N4302

403669 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
Q30	200088	TRANS	SILICO	PNP	2N4248		80131	2N4248
Q31	200043	TRANS	SILICO	NPN	2N3565		80131	2N3565
Q32	200088	TRANS	SILICO	PNP	2N4248		80131	2N4248
Q33	200129	TRANS			SE4020		07263	SE4020
Q34	200037	TRANS	SILICO	NPN	2N3646		80131	2N3646
Q35	200185	TRANS			2N5033		07263	2N5033
Q36	200099	TRANS			2N4258		01295	2N4258
Q37	200048	TRANS	SILICO	NPN DUAL	2N3565		80131	2N3565
Q38	200048	TRANS	SILICO	NPN DUAL	2N3565		80131	2N3565
Q39	200048	TRANS	SILICO	NPN DUAL	2N3565		80131	2N3565
Q40	200048	TRANS	SILICO	NPN DUAL	2N3565		80131	2N3565
Q41	200048	TRANS	SILICO	NPN DUAL	2N3565		80131	2N3565
R1	010765	RES	METAL	8.95 M		1%	81349	RN80C
R2	040188	RES	POT	100 K	360T		11237	360T
R3	010764	RES	METAL	845 K		1%	81349	RN65C
R4	040197	RES	POT	10 K	360T		11237	360T
R5	010763	RES	METAL	84.5 K		1%	81349	RN70C
R6	040196	RES	POT	1 K	360T		11237	360T
R7	010767	RES	METAL	9.5 K			81349	RN60C
R8	000101	RES	CARBON	100 OHM		5% 1/4W	81349	RC07GF101J
R9	000101	RES	CARBON	100 OHM		5% 1/4W	81349	RC07GF101J
R10	000101	RES	CARBON	100 OHM		5% 1/4W	81349	RC07GF101J
R11	000206	RES	CARBON	20 M		5% 1/4W	81349	RC07GF206J
R12	000914	RES	CARBON	910 K		5% 1/4W	81349	RC07GF914J

403669 · Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
R13	001807	RES	CARBON	910 K		5% 1/2W		
R14	000824	RES	CARBON	820 K		5% 1/4W	81349	RC07GF824J
R15	010772	RES	METAL	1 MEG		1%	81349	RN75C
R16	020638	RES	WW	100 K		5% 10 W	22045	M100
R17	000126	RES	CARBON	12 M		5% 1/4W	81349	RC07GF126J
R18	000472	RES	CARBON	4.7 K		5% 1/4W	81349	RC07GF472J
R19	040218	RES	POT	25 K	X201		11237	X201
R20	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R21	011178	RES	METAL	4.99 K		1% 1/4W	81349	RN20X4994F
R22	011178	RES	METAL	4.99 K		1% 1/4W	81349	RN20X4994F
R23	000750	RES	CARBON	75 OHM		5% 1/4W	81349	RC07GF750J
R24	000750	RES	CARBON	75 OHM		5% 1/4W	81349	RC07GF750J
R25	040222	RES	POT	500 OHM	X201		11237	X201
R26	000820	RES	CARBON	82 OHM		5% 1/4W	81349	RC07GF820J
R27	040239	RES	POT	1 M		10%	73138	89P
R28	010766	RES	WW	499 K		.1%	81349	RN60C
R29	010762	RES	METAL	49.9 K	SET	.1%	81349	RN55C
R30	010761	RES	METAL	4.99 K	SET	.1%	81349	RN55C
R31	010760	RES	METAL	499 OHM	SET	.1%	81349	RN55C
R32	010567	RES		453 OHM		1%	81349	RN55C
R33	040193	RES	POT	100 OHM	360T		11237	360T
R34	010421	RES		953 OHM		1%	81349	RN55C
R35	010759	RES	WW	1.8 K	SET	.5%	22045	2001A
R36	010759	RES	WW	1.8 K	SET	.5%	22045	2001A
R37	000513	RES	CARBON	51 K		5% 1/4W	81349	RC07GF513J

403669 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
R38	000204	RES	CARBON	200 K		5% 1/4W	81349	RC07GF204J
R39	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R40	040219	RES	POT	250 K	X201		11237	X201
R41	000623	RES	CARBON	62 K		5% 1/4W	81349	RC07GF623J
R42	000244	RES	CARBON	240 K		5% 1/4W	81349	RC07GF244J
R43	000201	RES	CARBON	200 OHM		5% 1/4W	81349	RC07GF201J
R44	000271	RES	CARBON	270 OHM		5% 1/4W	81349	RC07GF271J
R45	000104	RES	CARBON	100 K		5% 1/4W	81349	RC07GF104J
R46	000105	RES	CARBON	1 MEG		5% 1/4W	81349	RC07GF105J
R47	040268	RES	POT	1 MEG	X201		11237	X201
R48	000105	RES	CARBON	1 MEG		5% 1/4W	81349	RC07GF105J
R49	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R50	000222	RES	CARBON	2.2 K		5% 1/4W	81349	RC07GF222J
R51	000203	RES	CARBON	20 K		5% 1/4W	81349	RC07GF203J
R52	000203	RES	CARBON	20 K		5% 1/4W	81349	RC07GF203J
R53	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R54	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R55	000104	RES	CARBON	100 K		5% 1/4W	81349	RC07GF104J
R56	000332	RES	CARBON	3.3 K		5% 1/4W	81349	RC07GF332J
R57	000362	RES	CARBON	3.6 K		5% 1/4W	81349	RC07GF362J
R58	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R59	000114	RES	CARBON	100 K		5% 1/4W	81349	RC07GF114J
R60	000126	RES	CARBON	12 M		5% 1/4W	81349	RC07GF126J
R61	000225	RES	CARBON	2.2 M		5% 1/4W	81349	RC07GF225J
R62	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J

403669 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
R63	040219	RES	POT	250 K	X201		11237	X201
R65	000681	RES	CARBON	680 OHM		5% 1/4W	81349	RC07GF681J
R66	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R67	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R68	000152	RES	CARBON	1.5 K		5% 1/4W	81349	RC07GF152J
R69	000750	RES	CARBON	75 OHM		5% 1/4W	81349	RC07GF750J
R70	040215	RES	POT	1 K	X201		11237	X201
R71	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R72	000241	RES	CARBON	240 OHM		5% 1/4W	81349	RC07GF241J
R73	000750	RES	CARBON	75 OHM		5% 1/4W	81349	RC07GF750J
R74	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R75	040222	RES	POT	500 OHM	X201		11237	X201
R76	000272	RES	CARBON	2.7 K		5% 1/4W	81349	RC07GF272J
R77	000821	RES	CARBON	820 OHM		5% 1/4W	81349	RC07GF821J
R78	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R79	000101	RES	CARBON	100 OHM		5% 1/4W	81349	RC07GF101J
R80	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R81	010672	RES		1 K		.1%	81349	RN55E
R82	010749	RES		9 K		.1%	81349	RN55E
R83	010529	RES	METAL	10 K		1%	81349	RN55C
R84	010676	RES	METAL	15 K		1%	81349	RN55C
R85	010529	RES	METAL	10 K		1%	81349	RN55C
R86	000303	RES	CARBON	30 K		5% 1/4W	81349	RC07GF303J
R87	040196	RES	POT	1 K			11237	360T
R88	010753	RES	FSV			1%	81349	RN55E

403669 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
R89	000822	RES	CARBON	8.2 K		5% 1/4W	81349	RC07GF822J
R90	000303	RES	CARBON	30 K		5% 1/4W	81349	RC07GF303J
R91	000153	RES	CARBON	15 K		5% 1/4W	81349	RC07GF153J
R92	000822	RES	CARBON	8.2 K		5% 1/4W	81349	RC07GF822J
R93	000153	RES	CARBON	15 K		5% 1/4W	81349	RC07GF153J
R94	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R95	000753	RES	CARBON	75 K		5% 1/4W	81349	RC07GF753J
R96	000206	RES	CARBON	20 M		5% 1/4W	81349	RC07GF206J
R97	000153	RES	CARBON	15 K		5% 1/4W	81349	RC07GF153J
R98	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R99	000623	RES	CARBON	62 K		5% 1/4W	81349	RC07GF623J
R100	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R101	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R102	040270	RES	POT	1 K	3299W Type		80294	3299W-1-201
R103	010759	RES	WW	15.5 K	SET	.5%	22045	2001A
R104	010752	RES	FSV			1%	81349	RN55E
R105	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R106	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R107	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R108	000202	RES	CARBON	2 K		5% 1/4W	81349	RC07GF202J
R109	000203	RES	CARBON	20 K		5% 1/4W	81349	RC07GF203J
R110	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R111	000474	RES	CARBON	470 K		5% 1/4W	81349	RC07GF474J
R112	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J
R113	000102	RES	CARBON	1 K		5% 1/4W	81349	RC07GF102J

403669 – Assy., MAIN PC BOARD *continued*

REF DES	DANA P/N	DESCRIPTION					FSC	MANU P/N
R114	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R115	000512	RES	CARBON	5.1 K		5% 1/4W	81349	RC07GF512J
R116	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R117	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R118	000563	RES	CARBON	56 K		5% 1/4W	81349	RC07GF563J
R119	000103	RES	CARBON	10 K		5% 1/4W	81349	RC07GF103J
R120	000513	RES	CARBON	51 K		5% 1/4W	81349	RC07GF513J
R121	000206	RES	CARBON	20 M		5% 1/4W	81349	RC07GF206J
R122	000206	RES	CARBON	20 M		5% 1/4W	81349	RC07GF206J
R123	000126	RES	CARBON	12 M		5% 1/4W	81349	RC07GF126J
R124	040219	RES	POT	250 K	X201		11237	X201
R125	001771	RES	CARBON	1.8 OHM		5% 1/2W		
R126	000472	RES	CARBON	4.7 K		5% 1/4W	81349	RC07GF472J
S1	600647	SWITCH	ROTARY		600647		21793	600647
S2	600648	SWITCH	ROTARY		600648		21793	600648
T1	300074	TRANSFORMER, POWER					81160	300074A
T2	403634	ASSY	TRANSFORMER		403634		21793	403634

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